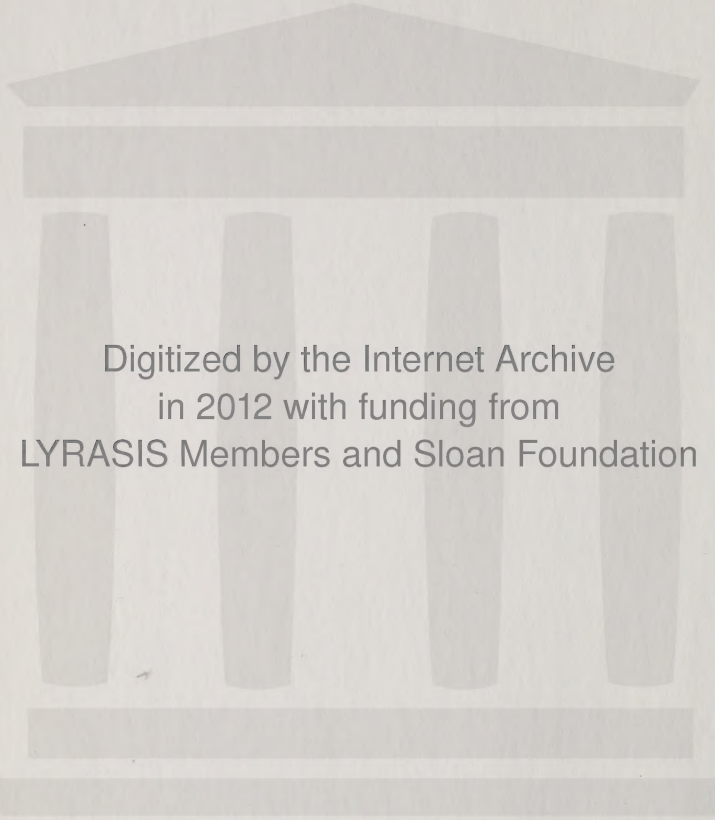




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PROCEEDINGS
of the
Indiana Academy
of Science

Founded December 29, 1885



Volume 83
1973



MARION T. JACKSON, *Editor*
Indiana State University
Terre Haute, Indiana



Spring Meeting
May 11-12, 1973
BROWN COUNTY STATE PARK, Nashville, Indiana

Fall Meeting
October 26-27, 1973
INDIANA CENTRAL COLLEGE, Indianapolis, Indiana

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Zoological Record

TABLE OF CONTENTS

Part 1

THE WORK OF THE ACADEMY

	Page
Officers and Committees for 1973	3
Minutes of the Spring Meeting (Executive Committee)	14
Minutes of the Spring Meeting (General Session)	16
Minutes of the Fall Meeting (Executive Committee)	18
Minutes of the Fall Meeting (General Session)	23
Annual Financial Report	25
Annual Report, Indiana Junior Academy of Science	29
Biological Survey Committee Report	32
Necrology	39
New Members for 1973	52

Part 2

ADDRESSES AND CONTRIBUTED PAPERS

Presidential Address	59
"Snakes Alive," WILLIAM B. HOPP	

Anthropology

P. J. PROVOST—Ahuili: A Rite of Reversal among the Eastern Nahua of the Huasteca Region of Northern Veracruz, Mexico*	63
R. E. PACE and G. APFELSTADT—Ceramics of the Multi-Component Farrand Site, Vigo County, Indiana*	63
G. L. BROUILLARD—Cultural Marginality of the Alto Caqueta*	63
V. A. REIDHEAD—An Argument for the Use of Probability Testing in Defining Vegetation Zones in Archaeological Reconstruction	64
T. P. MYERS and V. A. REIDHEAD—Site Stratification in a Lacustrine Environment: Evidence from Highland Ecuador	65
R. E. RIGGS—A Report on the Disposition of Ten Discontinuous Cranial Traits in the Indian Knoll Skeletal Population	74

Botany

C. FELLING and C. L. GEHRING—Early Development of Anthers in the Maize Mutant, Tassel Seed-2*	77
A. A. SUSALLA—Ultrastructure of Plastid Entities in Cells of Genetic Albino Leaf Callus of Phenotypically Green Origin*	77

* Abstract or Note only

	Page
D. J. MORRÉ—A Robust Form of <i>Echinochloa muricata</i> *	78
W. W. BLOOM—A Spore Viability in a Fifty-one-Year-Old Sporocarp of <i>Marsilea quadrifolia</i> *	78
T. R. MERTENS—Meiotic Chromosome Behavior in <i>Rhoeo spathacea</i> (Swartz) Stearn	79

Cell Biology

L. F. ELLIS and L. K. SAMPSON—Preparation of Microbes for Scan- ning Electron Microscopy (SEM)*	83
P. G. MAHLBERG—Scanning Microscopic Comparison of Starch Grains from the Latex of <i>Euphorbia</i> Species*	83
L. K. SAMPSON, G. BORDER and L. F. ELLIS—VLB Effects on CHO Cells As Seen by Scanning Electron and Phase Microscopy* ...	84
J. D. SCHOKNECHT, W. E. MAGEE and C. W. GOFF—A Cytological Study of the Uptake of Liposomes by HeLa Cells*	84
F. TWOHIG, D. J. MORRÉ and E. L. VIGIL—Properties and Subcellu- lar Distribution of Peroxidases of Onion Stem	86
R. BARR and F. L. CRANE—A Study of Chloroplast Membrane Poly- peptides from Mineral-Deficient Maize in Relation to Photosyn- thetic Activity	95
H. J. HARMON and F. L. CRANE—Topography of the Inner Mito- chondrial Membrane	105
W. N. YUNGHANS, J. H. ELDER, B. WINTERSTEEN and D. J. MORRÉ— Inhibition by DDT of Calcium Accumulation in Isolated Cell Fractions from Rat Muscle	113

Chemistry

L. S. HILL and E. BOSCHMANN—Why Square Planar Complexes Exist*	121
B. N. STORHOFF and A. J. INFANTE—Rhenium (I) Complexes of 2-Cyanophenyldiphenylphosphine*	121
P. L. BOCK and G. M. WHITESIDES—The Stereochemistry of Reactions at Carbon Transition Metal-Bonds*	122
M. SVOBODA and R. W. ROESKE—Synthesis and Catalytic Properties of a Cyclic Octapeptide*	122
S. M. KALBAG and R. W. ROESKE—Synthesis and Binding Properties of Cyclic Hexapeptides Containing CIS-4-Aminocyclohexane Carboxylic Acid*	122
D. R. HOGUE and E. S. WAGNER—Reaction Mechanism of Benzyl- penicillin with 2-Mercaptoethylamine*	123
W. E. GROVES and T. L. KRUGER—Synthesis and Cope Elimination of N-(2-Deuteroethyl)-N-ethyl aniline oxide*	123

	Page
T. L. KRUGER and H. F. BANEY—The Polonovski Reaction of Substitutes-N, N-diethylaniline Oxides*	124
E. SCHWARTZ and S. K. PORTER—Temperature Dependence of the Surface Tensions of Aqueous n-Heptanol Solutions*	124
R. H. L. HOWE—The Comparison of Calcium Hydroxide and Sodium Hydroxide for Chemical Processing Liquid Wastes Control and Purification*	124
R. C. KOILE and R. E. VAN ATTA—Physical and Chemical Evaluation of Used Motor Oil*	124
A. C. WORTHINGTON and J. H. MEISER—Diffusion of Ca^{++} , Mg^{++} , and Pb^{++} and their Interaction with Precipitated Amino Acid Barriers*	125
A. SIEGEL—High Resolution Mass Spectrum of Non-Vicinal $^{13}\text{C}_2$ Labeled Tropylium Iodide*	125
R. J. BINNION, J. H. MEISER and D. E. KOLTENBAH—Radiocarbon Dating of Indian Site Remains of Indiana*	125
C. E. WILSON—Computer Simulation of Titration Curves*	126
S. L. BURDEN and D. E. EULER—Titration Errors Arising from the Use of Gran Plots with Experimentally Obtained Data from a Strong Acid-Strong Base Titration*	126
G. A. SHERWOOD and R. E. VAN ATTA—An Experiment in Practical Polarography—Determination of Zinc and/or Manganese in Magnesium Alloys*	126
D. F. STORHOFF and E. S. WAGNER—Synthesis and Characterization of Penicilloyl-Poly-L-Cysteine: A Possible Skin Test Reagent for Penicillin Allergy*	127
G. R. BAKKER and J. W. LOEWENHERZ—Development of an Automatic Recording Apparatus for Gasometric Analyses at Constant Pressure	128

Ecology

M. T. JACKSON—Analysis of Possible Successional Trends Within the Tree Stratum in Old-growth Beech-maple Dominated Forests*	133
J. B. LEVENSON—The Groundlayer of the Beech-Maple Association: A Community Structure Analysis*	134
B. HOLLETT—A New Method for Extracting Tree Roots from Soil* ..	134
M. L. MCCLAIN—Site Preferences and Growth Responses of Kentucky Coffeetree, <i>Gymnocladus dioica</i> (L.) K. Koch, Near the Center of its Range*	135
P. A. EDDY—Bacterial and Chemical Analysis of Cardinal Creek Flowing through Ball State University, from May to December, 1972*	135

	Page
R. H. L. HOWE—The Limitation of Oxygen Demand Tests for Water Pollution Control*	136
J. M. SPROAT—Effect of Diquat upon the Root and Mycorrhiza System of <i>Liriodendron tulipifera</i> L.*	136
R. M. HOFFER, L. A. BARTOLUCCI and J. S. BERKEBILE—Assessment of Characteristics of Strip-mined Areas of Indiana*	136
H. M. DONSELMAN—An Ecological Analysis of the Shrub Stratum in the Beech-Maple Forest Type*	136
B. O. BLAIR and J. HERTEL—The Phenological Response of Five Perennial Plant Species at Five Locations in Indiana to Climatic Variations 1966-1972	139
R. J. SMITH and C. M. KIRKPATRICK—Microclimatic Measurements and Use of Artificial Shelter by Confined Cottontails	146
B. C. FISHER and C. MERRITT—The Anthracene-in-Benzene Chemical Light Meter	155
S. F. BINKLEY, B. C. FISHER and C. MERRITT—A Study of Light Distribution Within a Red Pine Canopy	162
H. S. JOHNSON, J. S. BERKEBILE and G. R. PARKER—An Ecological Inventory of Bryan Nature Preserve	167
R. G. WILLEY, M. J. DOSKOCIL and C. A. LEMBI—Potential of the White Amur (<i>Ctenopharyngodon idella</i> Val.) as a Biological Control for Aquatic Weeds in Indiana	173
D. A. WEBB and T. S. MCCOMISH—Food Habits of Adult Alewives in Lake Michigan Near Michigan City, Indiana, in 1971 and 1972	179
R. S. BENDA—Growth and Movement of Fish in the Vicinity of a Thermal Discharge	185

Engineering

W. D. KOVACS—The Seismicity of Indiana and Civil Engineering Structures*	193
J. A. SPOONER, A. R. RAO and B. T. CHENCHAYYA—The Relationship between Ground Water Levels, Precipitation, and River Stages*	193
R. M. PEART, J. E. NEWMAN and W. L. STIRM—Estimating 1973 Weekly Energy Use for Indiana Corn Drying by Simulation*	194
G. AGUIRRE and J. E. LINDELL—A Mathematical Modeling of Ground Water Contaminant Decay*	194
P. E. STANLEY—Biomedical Engineering and Health Care Delivery*	195
J. W. DELLEUR and M. T. LEE—Geomorphologic Characteristics of Fourteen Indiana Watersheds Obtained from a Computer Data Bank of Stream Networks	196

* Abstract or Note only

R. A. RAO and R. G. S. RAO—Application of Some Statistical Tests to Investigate the Urban Rainfall Characteristics	204
--	-----

Entomology

G. L. SPANGLER and R. E. SIVERLY—A Preliminary Report of Mosquito Population Sampling Methods in Delaware County, Indiana, 1973*	213
J. J. MCGIVERN—Non-Random Segregation of Interchange Complexes in a Compound Structural Rearrangement (Translocation + Inversion) in the Mosquito, <i>Aedes aegypti</i> *	213
R. E. SIVERLY and J. JOYNER—Notes on Identification and Biology of <i>Bufo lucilia silvarum</i> (Meigen) (Diptera, Calliphoridae) in East-Central Indiana*	214
J. W. BURGESS—Review of Findings on the Taxonomic Status of <i>Culex pipiens</i> L. and <i>Culex fatigans</i> Wiedemann in the United States*	214
E. LEVINE—Biology of <i>Bellura gortynoides</i> Walker (= <i>vulnifica</i> (Grote)), the Yellow Water Lily Borer (Lepidoptera: Noctuidae)*	214
T. M. LEE and R. E. SIVERLY—A Preliminary Study of Autogeny in Stenogamous and Nonstenogamous Strains of <i>Culex pipiens pipiens</i> (Northern House Mosquito)*	215
T. M. LEE and R. E. SIVERLY—Evaluation of ALTOSID SL-10 in Controlling Mosquito Populations in an Industrial Waste Lagoon Complex*	215
R. E. SIVERLY—Observations on the Biology of <i>Mansonia perturbans</i> (Walker) (Diptera, Culicidae) in Indiana*	216
D. L. SCHUDER—A New Barberry Pest Found in Indiana*	216
D. A. SHROYER and R. W. MEYER—New Distribution Records of Mosquitoes in Indiana, 1973 (Diptera: Culicidae)	218
G. L. WARD—Prey-taking Among some Indiana Solitary Wasps (Hymenoptera: Sphecidae)	220
J. W. HART—Preliminary Ecological Research Center, Including New Records of Indiana Springtails	224
R. W. MEYER—Insects and Other Arthropods of Economic Importance in Indiana during 1973	230

Geography and Geology

R. L. POWELL—Coal Mine Subsidence Problems in Indiana*	239
P. M. CASEROTTI and G. MARLAND—Impact of Coal Mine-Waste Runoff on a Small Stream*	239
C. E. WIER—Fossil Fuels and the Energy Crisis in Indiana*	240

	Page
N. Z. BOCTOR and G. KULLERUD—The Mineralogy and Geochemistry of Mercury Ore from the Senator Mine, Nevada, in the Light of Experimental Studies*	240
W. W. DAVIS—Formation of Silicious Stones: Agate*	241
J. B. PATTON—Masonry Materials in Historic Indiana Structures* ..	241
T. GOGNAT and S. S. SHIMER—What God and Man Have Wrought*	241
A. J. RUDMAN, M. E. BIGGS, R. F. BLAKELY and J. F. WHALEY—Preliminary Study of Interrelationships of Resistivity and Velocity in Indiana Lithologies*	242
G. J. SHEA—Should Indiana be Prepared for a Shock?*	242
W. J. WAYNE—Multiple Tills at Wabash, Indiana*	242
H. COLLINS and L. A. BROWN—Fracture Analysis of the Kentland, Indiana, Disturbance*	243
T. J. STEVENS—A Meso-Scale Analysis of the Journey to Work: The Example of the Burley Tobacco Farmer	244
W. D. BROOKS—The Universal Transverse Mercator Grid	250
W. J. TODD—Urban Land Use Identification in the Gary-Hammond Area by Computer Analysis of Multispectral Satellite Data ...	259
J. M. WILKERSON, R. J. SETTE and T. R. WEST—Environmental Geology and Land-Use Planning in Boone and Tippecanoe Counties, Indiana	269
R. F. BONEHAM—Environmental Study of Howard County, Indiana: Geologic Aspects	278
A. J. RUDMAN, M. E. BIGGS, R. F. BLAKELY and J. F. WHALEY—Statistical Studies of Indiana Bedrock Velocities: Mapping Applications	284
M. M. VARMA and R. F. BLAKELY—Applications of Intensity-Epicentral Distance Relations to Earthquakes Affecting Indiana	292
R. H. SHAVER—The Niagaran (Middle Silurian) Macrofauna of Northern Indiana: Review, Appraisal, and Inventory	301

History of Science

W. E. EDINGTON—Indiana Women in Mathematics*	317
J. J. FAVINGER—Indiana Contributions to the National Plant Board*	317
B. E. MONTGOMERY—Linnean "Elements" in the Indiana Fauna and Flora	319
W. J. TINKLE—Creationism in the Twentieth Century	330
W. R. EBERLY—A. B. Ulrey: Pioneer Biology Teacher at Manchester College 1894-1900	335

Microbiology and Molecular Biology

Page

R. L. TRUITT and M. POLLARD—Therapy of Leukemic AKR Mice by Allogeneic Bone Marrow Transplantation*	341
M. POLLARD—Prostate Carcinomas in Germfree Rats*	341
I. H. MATHER and B. J. TAYLOR—The Effect of Nicotinamide Adenine Dinucleotide (NAD) and Nicotinamide Adenine Dinucleotide Phosphate (NADP) on the NAD Glycohydrolase-inhibitor Complex of <i>Pseudomonas putida</i> KBI	343
J. ROMANO and R. L. NICHOLSON—Extracellular Pectic Enzymes Produced by <i>Colletotrichum graminicola</i>	351
J. J. GAVIN—The Therapeutic Promise of Molecular Biology	357

Physics

J. L. LEPERA, D. E. KOLTENBAH and J. H. MEISER—Liquid Scintillation Technique for Radiocarbon Dating of Samples of High Organic Content*	369
W. W. DAVIS—An Optical Instrument for Viewing Near-flat Surfaces: The "Toposcope"*	369
G. M. CRAIG and G. P. THOMAS—Thermodynamic Considerations in Devising an External Combustion Gas Turbine Engine Refuse Incinerator*	369
H. H. SNYDER—Some New Solutions of Schrodinger's Equation in Spherical Coordinates*	370
C. J. BASANAVICUS, P. R. ERRINGTON and J. P. COLLINS—Holography Made Easy*	370
M. E. HULTS, D. W. WARN, D. A. MITCHELL and G. D. BARTON—Optical, Radio and Temperature Observations at the 10 July 1972 and 30 June 1973 Total Solar Eclipses	371
K. L. BOWERS, R. H. KAITCHUCK, G. E. TOMLINSON and D. A. MITCHELL—Shipboard Visual and Photographic Observations of the 30 June 1973 Total Solar Eclipse	382
D. L. LOVE—The Terre Haute Astronomical Object List (THAOL) Program: A Public Relations and Teaching Resource	385
C. W. MILLER—Daily and Weekly Changes in Total Suspended Particulate Matter Concentrations at Anderson, Indiana	389
R. J. VETTER, P. L. ZIEMER and O. L. CONOVER—Anechoic Chamber Design for Microwave Research	393

Plant Taxonomy

C. P. MCHUGH—A Numerical Taxonomic Study of Some North American Species of <i>Pinus</i> *	397
C. B. HEISER, JR.—A Spontaneous Hybrid of <i>Capsicum annuum</i> var. <i>minimum</i> and <i>Capsicum frutescens</i> *	397

	Page
T. J. CROVELLO and C. KELLER—Uses of Computerized Floristic Data of Indiana for Plant Geography	399
T. J. CROVELLO—A Computerized Flora of Indiana: Its Scope, Value and Feasibility	407

Science Education

A. DEVITO—Teaching Science Creatively in the Elementary School*	411
L. E. POORMAN and M. D. SMITH—The Art of Innovation: A Study of the Mechanics of Being Creative*	411
R. BURTCH—Literature Review: Creationists <i>vs.</i> Evolutionists in California*	412
G. H. KROCKOVER—Teaching Science Through Interest Centers* ...	412
J. M. SMITH—Solar System: An Educational Play*	412
J. A. RHOADES—A Science Program Designed to Prepare Sixth Graders for ISCS*	412
C. M. BOENER—Commitment to Science in Elementary Schools: A Survey Report*	413
K. W. UHLHORN—Pictures of Scientists as Drawn by Children and Their Concept of Science*	413
V. E. NEIE—An Experimental Program in Physical Science for Prospective Elementary Education Majors*	414
C. M. BOENER—Two Multidiscipline Sciences Degree Programs: A Survey Report*	414
R. K. CAUDELL—The Use of Individualized Media for Selected Environmental Topics with the Prospective Elementary Teacher*	414
M. E. PARKS—An Experimental Environmental Science Program for Undergraduates*	415
V. E. NEIE—Teaching Good Optics Through the Physics of Photography—A Minicourse for a Variety of Purposes*	415
A. E. LAWSON—Relationships Between Concrete and Formal Intellectual Level of the Learner*	416
D. W. BALL—Faculty-course Evaluation: An Effort in Mutual Communication*	417
C. L. SMILEY—A Comparative Study of Compulsory <i>vs.</i> Non-Compulsory Attendance in Secondary Biology Using the Systems Approach to Biology Program as the Method of Teaching*	419
W. D. BROOKS—Science Teaching and Teacher Verbalization	421

Soil and Atmospheric Sciences

Page

S. J. KRISTOF and M. F. BAUMGARDNER—Mapping Soil Patterns with Multispectral Data from the Earth Resources Technology Satellite*	429
D. R. HENDRICKS and D. D. WATERS—Growth Results of Black Walnut (<i>Juglans nigra</i>) Seedlings of Different Seed Sources on Soils of East-Central and Southeastern Indiana 1967-1972*	430
H. W. OHM—Effect of Nitrogen and Herbicides on Oat Grain Protein Content*	430
D. W. NELSON and R. K. STIVERS—Relationship of Soil Fertility Practices to the Nitrate Content of Drainage Water from Indiana Soils*	431
C. R. CHURCH and M. D. ABEL—Determinations of the Atmospheric Electric Conduction Current*	431
W. R. GOMMEL and R. A. GOMMEL—Air Temperature Fluctuation Aboard the <i>Massalia</i> During the Eclipse of 30 June 1973*	431
F. W. SANDERS and D. FRANZMEIER—Classification of Some Dark Colored Northern Indiana Soils	433
G. C. STEINHARDT, P. W. HARLAN, S. J. ROSS and D. P. FRANZMEIER—Micromorphological Analysis of Selected Indiana Soils	439
R. K. STIVERS—Productivity of Selected Indiana Soils	446
S. G. STUFF and R. F. DALE—Soil Water Tables Under Corn on Tile-Drained Chalmers Silt Loam	454

Zoology

J. E. ALBRECHT and L. L. HEARSON—An Analysis of the Nerve-mitotic Distribution in the Regenerating Forelimb of the Axolotl, <i>Ambystoma mexicanum</i> *	465
R. D. KIRKPATRICK and A. M. CARTWRIGHT—List of Mammals Known to Occur in Belize, Central America*	465
D. A. JONES—Blood Characteristics and Activity of some Neotropical Frogs*	465
C. SINCLAIR and J. A. ALBRIGHT—Maternal Behavior in Domestic and Wild Swine: An Ethological Approach*	465
V. H. RESH—Diversity, Stability and Temporal Organization of a Stream Caddisfly Community*	466
J. F. BELLON and W. J. BRETT—Blood Clearance and Tissue Uptake of Aminoglutethimide*	466
T. JOSEPH—Coccidia from the Opossum, <i>Didelphis virginiana</i> (Kerr)*	467
S. A. MINTON—Observations on Sea Snakes at Ashmore Reef, Timor Sea*	467

* Abstract or Note only

	Page
J. O. WHITAKER, JR., and W. A. MILLER—Rabies in Bats of Indiana: 1968-1972	469
E. P. BARTON, S. L. DONALDSON, M. A. ROSS and J. L. ALBRIGHT— Social Rank and Social Index as Related to Age, Body Weight and Milk Production in Dairy Cows	473
J. O. WHITAKER, JR., and L. L. SCHMELTZ—Food and External Parasites of the Eastern Mole, <i>Scalopus aquaticus</i> , from Indi- ana	478
J. B. COPE, A. R. RICHTER and R. S. MILLS—A Summer Concentra- tion of the Indiana Bat, <i>Myotis sodalis</i> , in Wayne County, Indiana	482
Instructions for Contributors	485
Acknowledgement of Reviewers	487
Index	489

* Abstract or Note only

PART 1

THE WORK
OF THE
ACADEMY

1973

W. B. HOPP, *President*

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WINONA H. WELCH.....	DePauw University Greencastle, IN 46135

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A. J. ULLSTRUP (1973).....	Department of Botany and Plant Pathology Purdue University West Lafayette, IN 47907
H. G. DAY (1974).....	Department of Chemistry Indiana University Bloomington, IN 47401

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S. N. POSTLETHWAITE.....	Department of Biological Sciences Purdue University West Lafayette, IN 47907

Academy Representative on Indiana Natural Resources Commission

D. W. OSGOOD.....	Department of Zoology Butler University Indianapolis, IN 46208
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SPRING MEETING

BROWN COUNTY STATE PARK, Brown County, Indiana

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

May 11, 1973

The meeting was called to order at 4:00 PM at Abe Martin Lodge, in Brown County State Park by President William B. Hopp. The minutes of the general session meeting of November 3, 1972, were approved.

Treasurer: Clyde Metz reported that the 1972 books have been closed and the audit is complete.

Academy Foundation: James Magee, of the Indiana National Bank, Indianapolis, reported on the three investment funds of the Academy. These funds are 1) the John S. Wright Fund, 2) the John S. Wright Invested Income Account, and 3) the Foundation Account. Mr. Magee explained the basis for the three types of funds and how each should be used in the management of Academy business.

Publications Committee: Marion Jackson reported that the State appropriation for support of the *Proceedings* had been reduced from \$4,000 to \$1,200. Following discussion concerning ways to realize savings in publication costs, Dr. Jackson made the following motion which was seconded and passed.

Motion: That Vol. 83 of the *Proceedings* be published only in soft bound cover.

The advantages and disadvantages of assessing page charges were presented. No action was taken.

The Executive Committee was requested to give reactions to the Publications Committee on the advisability of instituting an editorial board which would 1) assist the editor in evaluating manuscripts and 2) assist the editor in identifying reviewers. Action on this item of business will be requested at the Fall Meeting.

Announcements: President Hopp made the following announcements.

The History of Science Division will be reactivated for the 1973 Fall Meeting with John J. Favinger serving as Chairman.

A request has been received to reactivate the Psychology Section under the new name of Animal Behavior. The request will be taken under advisement for possible action at the Fall Meeting.

A committee will be identified to study possible realignment of divisions in the areas of the earth sciences, hydrology, and atmospheric sciences.

Valparaiso University has invited the Academy for the 1976 meetings.

The Minton Monograph may be obtained for \$3.00 by contacting Lois Burton at the Indiana State Library, Indianapolis, IN 46204.

The Science and Society Committee worked with the State Legislature in an effort to establish a State Council on Science and Technology. The bill was passed by the House Committee, but the Senate Committee had insufficient time to act on the bill prior to end of the legislative session.

Executive Secretary Feasibility Study: Otto Behrens presented a report from the Executive Secretary Feasibility Study Committee. The possibility of generating funds for the salary of an Executive Secretary through sustaining memberships was suggested. The possibility of establishing a central office for mail service was proposed as an interim measure for expediting business affairs of the Academy. The report was received with no action taken on the proposals.

New Business: Consideration was given to the possibility of establishing earlier dates in October and earlier dates in April for Academy meetings.

Consideration was given to the idea of having the election of officers conducted at the Business Session of the Fall Meeting rather than at the Dinner Session.

The meeting adjourned at 5:15 PM.

Approved October 25, 1973.

Respectfully submitted,
JERRY J. NISBET, Secretary

MINUTES OF THE GENERAL SESSION

May 11, 1973

The meeting was called to order at 8:55 PM at Abe Martin Lodge, Brown County State Park, Brown County, Indiana, by President William B. Hopp. Announcements were made relative to the actions and reports of the May 11, 1973, meeting of the Executive Committee.

A special meeting for Chairmen of Academy Divisions was held to discuss responsibilities of Chairmen and to clarify points related to publication of the *Proceedings*.

Responsibilities of Division Chairmen:

- 1) Arrange Division program for the Fall Meeting. An announcement about paper sessions is made by the Newsletter editor during June. A preliminary call for papers is made in the late summer Newsletter. A list of Division members is sent to the Division Chairman in August. The chairman may use this list to prepare a separate mailing to solicit papers.
- 2) Arrange for election of Division Chairman and Chairman-elect for succeeding year. Conduct election as the last item of business in the morning session of the Fall Meeting. Report the results of the election to the secretary of the Academy.

Points Related to Publication:

- 1) In the call for papers mention that three (3) copies of the abstract are required.
- 2) The *full* address of authors is required.
- 3) Abstracts are submitted to the Division Chairman at the time a person requests the privilege of presenting a paper.
- 4) The abstract is automatically printed in the *Proceedings* (except for papers selected to be printed in full) unless the author requests that his/her abstract not be printed.
- 5) Selection of papers to be printed in full is based upon editorial decisions. Papers submitted are not automatically printed in full in the *Proceedings*.
- 6) A three-week deadline following the Fall Meetings must be observed for contributors to submit manuscripts to the editor. Two copies of each manuscript are requested.
- 7) Instructions for contributors are available from the editor of the *Proceedings*.
- 8) Publication of papers is restricted to members of the Academy (or at least one of the authors must be a member).
- 9) Papers in the *Proceedings* will follow the order in which they are read at the paper session.

- 10) Papers are not accepted for publication in the *Proceedings* unless they have been read at an Academy meeting.

The meeting adjourned at 10:15 PM.

Approved October 25, 1973.

Respectfully submitted,
JERRY J. NISBET, Secretary

FALL MEETING

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

INDIANA CENTRAL COLLEGE, Indianapolis, Indiana

October 25, 1973

The meeting was called to order by President William B. Hopp at 7:35 PM in Schwitzer Center, Indiana Central College, Indianapolis, Indiana. The minutes of the executive committee meeting and of the general session of the spring 1973 meeting of the Academy were approved with editorial changes. The following reports were accepted by general consent unless a specific motion is recorded.

Treasurer: Clyde Metz made a financial report for the period January 1 through October 15, 1973. The summary from this report follows:

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1973 -----	\$8,138.52	\$20,913.33	\$29,051.85
1973 Income -----	8,948.73	57,388.00	66,366.73
1973 Expenditures -----	7,687.58	56,223.06	63,910.64
Balance: October 25, 1973 -----	9,399.67	22,078.27	31,477.94

The Treasurer reported that transfer of funds from the J. S. Wright fund to Academy funds in the amount of \$4,226.87 for attorney fees was not required. Attorney fees were paid from regular Academy funds. Following discussion, the following motion was moved, seconded and carried; "that the money authorized to be transferred from the J. S. Wright fund to Academy funds for the purpose of paying attorney fees, be left in the J. S. Wright fund." (The authorization to transfer this money to Academy funds was not necessary to meet the cost of attorney fees. The money has remained in the J. S. Wright fund. The Executive Committee is empowered to decide how this reserve money may be used in the future.)

Bonding Committee: No report

Research Grants Committee: James Newman, Chairman, reported that \$5,441.40 had been granted to 10 individual research projects this year. Nine grants were made to institutional scientists and one to a high school student. Dr. Newman indicated that grants covered supplies and expenses with very little funding considered for capital expenses and no funding allowed for institutional overhead. He suggested that grants up to \$1,000 might be considered and that the number of grants could be extended.

Trustees of the Academy Foundation: W. A. Daily presented the following summary report:

I. Foundation Fund as of September 30, 1973	
Last year's balance as of Sept. 30, 1972 -----	\$ 994.52
Receipts -----	721.09

Disbursements -----	300.00
Balance -----	\$ 1,415.61

As of Oct. 5, 1973, \$1,000 was removed and invested in commercial paper.

II. John S. Wright Fund

Last year's balance as of Sept. 30, 1972 -----	\$26,000.00
Cash balances as of Sept. 30, 1972 -----	635.32
Receipts this past year -----	13,633.84
Disbursements -----	22,969.41
Balance -----	\$17,299.75
Commercial paper remaining as of Sept. 30, 1973 -----	16,000.00
Principal cash on hand -----	\$ 1,299.75

Academy Representative on the AAAS Council: Willis Johnson reported that the provision for direct representation on the AAAS Board has been abolished. He urged that the Academy continue to maintain affiliation with AAAS through representation on the AAAS State Academy body. (AAAS Section X)

Auditing Committee: No report

Youth Activities Committee: Donald Winslow reported that one of the major accomplishments of the year was realized through working with the Indianapolis Humane Society in the preparation of a joint resolution on the use of animals in the classroom. Details of the 26th annual Indiana Science Talent Search and of the Science Club Activity grants were described.

Indiana Junior Academy of Science: Lawrence Poorman reported on steps which are being taken to reorganize sponsored Academy youth programs. Plans call for the development of eight regions within the state, each with local sponsors. A Junior Academy Council is to be organized and a constitution committee will be formed. Dr. Poorman also reported that eight representatives from the Junior Academy will visit sessions of the Academy at the 1973 fall meeting. Six invited student papers will be presented on the second day of the Fall 1973 Academy Meeting.

Library Committee: Lois Burton reported that the special project to re-catalog the Academy's library collection has been completed. The project has involved re-cataloging 3,263 titles with the cards filed in the public catalog of the State Library. During the year, additional shelving was installed and the entire library collection has been shifted and is now housed in one location. Monograph Number 3, *Amphibians and Reptiles of Indiana* by Sherman A. Minton, Jr., was received from the printer on January 31, 1973, and is available from the Academy library. The Academy's *Proceedings* Volume 81, was received from the printer on February 28, 1973, and was mailed to 1,147 members and science clubs. Copies of Volume 81 were also mailed to foreign and domestic exchange agencies.

Program Committee: Edward Vondrak reported that all arrangements had been completed for the fall meeting. Some problems arose in the area of budget, and the suggestion was made that the budget for the Program Committee be enlarged for next year.

Publications Committee: Marion Jackson reported that Volume 82 of the *Proceedings* should be available from the printer before the end of December 1973. Division chairmen are reminded to send two copies of each abstract to the editor. One hundred seventy-five papers are scheduled for presentation at the 1973 fall meeting. This is the largest number of papers ever scheduled for a fall meeting of the Academy. Dr. Jackson reported that the Indiana State Museum has invited the Academy to allow the Museum to sell Academy monographs. Following discussion the following motion was seconded and passed: "That the Publications Committee be permitted discretion in authorizing sales of monographs to the Indiana State Museum at appropriate discounts."

Director of Public Relations: Clarence Dineen reported that copies of the Newsletter have been sent to schools in addition to members of the Academy this year. Efforts to expand news coverage for the Academy through the Newsletter are being implemented. Officers and members of the Academy are encouraged to send pertinent items to Dr. Dineen.

Membership Committee: Damian Schmelz reported that one Academy member in each science department of each college and university in the state has been asked to share information about the Academy with faculty. This action has been taken to stimulate interest in membership. The dues structure approved by the Executive Committee for 1972 and which is now in effect is:

Individual and club membership	-----\$6.00
Student membership	-----\$3.00
Family membership	-----\$8.00

A recommendation was made that an effort be made to systematically identify members who have reached retirement age and are thus eligible for emeritus membership. Following a discussion of the need for revision in membership categories, a motion to create the following categories of membership was seconded and passed:

1. Corporate Membership

Eligibility: any profit corporation

Dues: \$150-500 annually, according to size and technological base

Privileges: non-voting

Publications: 1 copy of *Proceedings* and monographs; Newsletter and notices to 5-10 personnel.

2. Institutional Membership

Eligibility: colleges, universities, non-profit organizations in Indiana

Dues: \$50 (fewer than 5,000 students), \$100 (more than 5,000) annually

Privileges: non-voting

Publications: 1 copy of *Proceedings* and monographs; Newsletter and notices to 5-10 science chairmen, deans, etc.

Privileges: non-voting; may present and publish papers

3. Individual Memberships

a. Annual Memberships

1) Student Membership

Eligibility: undergraduate or graduate student (5-year limit)

Dues: \$2.00

Publications: Newsletter and notices

2) Membership

Eligibility: any person interested in science

Dues: \$5.00

Privileges: all

Publications: Newsletter and notices

3) Senior Membership

Eligibility: any person interested in science

Dues: \$10.00

Privileges: all

Publications: Newsletter, notices, *Proceedings*

4) Sustaining Membership

Eligibility: any person interested in science

Dues: \$25.00

Privileges: all

Publications: Newsletter, notices, *Proceedings*, monographs

5) Fellows Membership

Eligibility: recommendation by Committee on Fellows, approval by Executive Committee

Dues: \$15.00

Privileges: all

Publications: all

b. Emeritus Membership

Eligibility: recommendation by Emeritus Member Selection Committee, approval by Executive Committee

Dues: none

Privileges: all

Publications: all

c. Life Membership

Eligibility: any individual member in good standing

Dues: \$300.00

Privileges: all

Publications: all

d. Honorary Membership

Eligibility: recommendation by Executive Committee

Dues: none

Privileges: all

Publications: all

4. Club Membership

Eligibility: any Indiana Junior or Senior High School Science Club, recommendation by Director of the Junior Academy, approval by Executive Committee

Dues: \$5.00

Privileges: non-voting; according to Junior Academy activities

Publications: Newsletter, notices

Fellows Committee: Benjamin Moulton moved: That the following individuals be elected as Fellows of the Academy:

DAMIAN V. SCHMELZ

GEORGE BICK

JOHN M. FERRIS

VIRGINIA R. FERRIS

ROBERT D. MILES

WALTER J. WEBER

THEODORE J. CROVELLO

WILLARD F. YATES, JR.

Seconded and passed.

Invitations Committee: Philip St. John moved: That the following invitations to host Academy meetings for the years indicated be accepted:

Valparaiso University 1976

Indiana University/Purdue University at Indianapolis 1977

Anderson College 1978

Seconded and passed.

Necrologist: No report

Parliamentarian: No report

Science and Society Committee: Harry Day reported that the committee has been active in sponsoring legislative action to establish a Science and Technology Council in Indiana. The bill will be presented again in this year's legislative session.

Resolutions Committee: Howard Youse discussed two resolutions and received the approval of the Executive Committee to present these resolutions at the General Session of the Academy on October 26, 1973.

Emeritus Member Selection Committee: Winona Welch moved: That the following individuals be awarded Emeritus Membership in the Academy:

WILLIAM C. BABCOCK, SR., Palm Desert, California
ARTHUR TALLMAN, Hendersonville, North Carolina
HAROLD E. WOLFE, Bloomington, Indiana
ANDREW T. SMITHBERGER, South Bend, Indiana

Seconded and passed.

Speaker-of-the-Year Committee: Willis Johnson reported that Dr. Durward L. Allen, Professor of Wildlife Ecology, Purdue University, has been selected speaker of the year for 1973-74. The topic of his address is, "The ecology of wolves and their prey on Isle Royale."

Executive Secretary Committee: Otto Behrens reported that after studying financial implications the committee recommends that no action be taken on establishing the office of Executive Secretary at this time.

Academy Representative on Indiana Natural Resources Commission: D. W. Osgood reported that input by the Academy representative was favorably received and was considered to be useful by the Commission. Mr. Osgood recommended that the term of office for the Academy's representative on the Commission be increased from one to several years to make greater use of the knowledge and contribution which the representative could thus have as a working member of the Commission.

New Business: William Gommel moved that the name of the Soil Science Division be changed to Soil and Atmospheric Sciences Division. Seconded and passed.

The meeting adjourned at 10:15 PM.

Respectfully submitted,
JERRY J. NISBET, Secretary

MINUTES OF THE GENERAL SESSION

October 26, 1973

The meeting was called to order by President William B. Hopp at 1:05 PM in Esch Hall Auditorium, Indiana Central College, Indianapolis, Indiana.

Dr. Gene E. Sease, President of Indiana Central College welcomed the Academy to Indiana Central College.

The secretary presented a summary of action taken by the Executive Committee at the Spring 1973 and at the Fall 1973 meetings.

Fay Daily presented the Necrologist's report. The report included the names of eight members:

O. B. CHRISTY	FLOY HURLBUT
P. D. EDWARDS	EARL T. MCBEE
PAUL R. FOLTZ	C. S. MORRIS
FRANK T. GUCKER	O. H. SMITH

A new procedure for electing officers of the Academy was initiated this year. The Nominating Committee presented its slate to the membership during the Business Session rather than at the evening banquet. Howard Youse, Chairman of the Committee, placed the following slate in nomination:

President:	DAMIAN V. SCHMELZ
President Elect:	JOHN B. PATTON
Research Grants:	CHARLES M. KIRKPATRICK (5-year term 1978)
Bonding Committee:	ROBERT M. BROOKER
Academy Foundation:	FRANK A. GUTHRIE (2-year term 1975)

The slate was accepted and a motion was made: That the secretary cast a unanimous ballot for the candidates. Seconded and passed.

Howard Youse moved the adoption of the following resolution on behalf of the Resolutions Committee:

That the Academy members here assembled express their appreciation to Dr. Gene E. Sease, President of Indiana Central College, for all the courtesies which have been extended the membership of the Academy during this meeting. We are particularly grateful to Professors Kenneth D. Borden and Edward A. Vondrak who were Co-chairmen of the Program Committee for their fine work in the preparation of the program. The arranged facilities for all programs at this annual meeting were excellent. Further, the Academy members are appreciative of the address of Dr. Durward L. Allen, who is Indiana Academy of Science Lecturer-of-the-Year. We also wish to thank Dr. Harry G. Day and the panel members for their discussion of a bill to establish an Indiana Council on Science and Technology.

Seconded and passed.

Howard Youse moved the adoption of the following resolution on behalf of the Resolutions Committee:

WHEREAS: State government needs scientific and technological counsel in dealing with many of the problems facing government and society today; and

WHEREAS: The creation of a highly competent *Council on Science and Technology* would provide the Governor and General Assembly a ready source of relevant information, which would facilitate good decision making; and

WHEREAS: Many competent scientists and engineers in this state have expressed an interest in assisting the Governor and General Assembly in this way, be it therefore

RESOLVED: That the Indiana Academy of Science strongly supports the establishment of a *Council on Science and Technology* as provided for in a bill to be sponsored in the 1974 session of the General Assembly by Representatives Gaylord and Hall, and Senators Andrews and Bruggenschmidt, and be it further

RESOLVED: That the Secretary of the Academy be instructed to convey this resolution to the Governor of the State, the Speaker of the House, and the President pro tem of the Senate; and that the Academy's Director of Public Relations be empowered to release this resolution to the public media.

Seconded and passed.

The Academy Speaker of the Year, Durward L. Allen, was introduced by William Hopp. Dr. Allen's illustrated lecture on "The ecology of wolves and their prey on Isle Royale" proved to be both fascinating and educational.

Harry G. Day presided over a special panel discussion on "The role of an Indiana Council on Science and Technology." Panel members were:

Legislators—Senator Jess C. Andrew, Jr., Senator Joseph G. Bruggenschmidt, Representative Francis Gaylord, Representative Thomas W. Hall.

Committee on Science and Society—Otto K. Behrens, Robert E. Henderson, Willis Johnson, Robert D. Miles, John B. Patton.

The meeting was temporarily adjourned and was reconvened at 6:30 PM with President-elect Damian V. Schmelz presiding at the annual banquet in Schwitzer Hall, Indiana Central College.

The Presidential Address titled, "Snakes Alive" was presented by Dr. William Hopp. His use of living specimens contributed an unusual element of intrigue to his entertaining lecture.

Respectfully submitted,
JERRY J. NISBET, Secretary

FINANCIAL REPORT OF THE INDIANA ACADEMY OF SCIENCE

JANUARY 1-DECEMBER 31, 1973

I. ACADEMY ACCOUNTS

	Income	Expenditure	Budgeted
Dues -----	\$ 5,951.00	-----	(\$ 5,600.00)
Reprints: Vol. 81 -----	2,863.20	2,845.44	(100.00)
Interest -----	1,057.41	-----	(1,000.00)
Miscellaneous -----	-----	-----	-----
Secretary -----	-----	652.30	600.00
Clerical -----	620.00	-----	-----
Office -----	32.30	-----	-----
Treasurer -----	-----	203.82	225.00
Clerical -----	-----	-----	-----
Office -----	203.82	-----	-----
General Office -----	-----	151.60	250.00
Travel, AAAS Dues, etc. -----	-----	207.50	200.00
Membership Committee -----	-----	63.39	75.00
Transfer to Administered Accounts -----	-----	2,750.00	2,750.00
Junior Academy -----	300.00	-----	-----
Science and Society -----	300.00	-----	-----
Natural Areas -----	200.00	-----	-----
Library Binding -----	1,000.00	-----	-----
<i>Proceedings</i> : Publication -----	750.00	-----	-----
<i>Proceedings</i> : Mailing -----	200.00	-----	-----
President's Fund -----	-----	-----	100.00
Newsletter -----	-----	75.09	225.00
Speaker of the Year -----	-----	-----	-----
Honorarium -----	-----	500.00	500.00
Administrative Expenses -----	-----	-----	50.00
Program Committee -----	-----	705.28	600.00
Chairman's Local Expenses -----	25.00	-----	-----
Printing -----	595.00	-----	-----
Mailing -----	85.28	-----	-----
Publications Editor's Expenses -----	-----	500.00	500.00
Youth Activities -----	-----	25.00	50.00
Public Relations -----	-----	18.50	50.00
CPA Fees -----	-----	525.00	500.00
Miscellaneous -----	-----	60.00	-----
Attorney Fees -----	60.00	-----	-----
	\$ 9,871.61	\$ 9,282.92	\$ 6,675.00

II. ADMINISTERED ACCOUNTS

	January 1 Balance	1973 Income	1973 Expenditures	December 31 Balance
Junior Academy -----	\$ 200.00	\$ 300.00	\$ 51.39	\$ 448.61
Science Talent Search -----	1,828.29	1,772.46	1,682.42	1,918.33
Science Fairs -----	4,334.06	20,850.54	22,739.70	2,444.90
Science and Society -----	1,875.57	300.00	301.87	1,873.70
Research -----	402.47	5,438.00	5,441.40	399.07
Natural Areas -----	826.50	200.00	-----	1,026.50
J. S. Wright Library -----	134.28	-----	-----	134.28
Lilly III Library -----	2,632.76	-----	-----	2,632.76
Lilly IV Library -----	2,693.95	-----	2,693.95	-----
Lilly V Library -----	-----	13,100.00	5,579.30	7,520.70
Library Binding -----	.90	1,000.00	955.35	45.55
Publications: -----	-----	-----	-----	-----
<i>Proceedings</i> -----	2,358.34	4,680.00	6,146.36	891.98
<i>Mailing of Proceedings</i> -----	139.32	200.00	-----	339.32
Monographs -----	-----	12,483.00	12,054.98	428.02
Natural Features -----	-----	-----	-----	-----
HEW Grant -----	3,486.89	750.00	4,236.89	-----
	\$20,913.33	\$61,074.00	\$61,883.61	\$20,103.72

III. SUMMARY

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1973 -----	\$ 8,138.52	\$20,913.33	\$29,051.85
1973 Income -----	9,871.61	61,074.00	70,945.61
1973 Expenditures -----	9,282.92	61,883.61	71,166.53
Balance: December 31, 1973 -----	8,727.21	20,103.72	28,830.93

IV. BANK BALANCES

First Bank and Trust Company, Indianapolis, Indiana -----	\$10,743.42
Great Western Savings and Loan, Los Angeles, California -----	12,551.45
First Western Savings and Loan, Las Vegas, Nevada -----	5,536.06
	\$28,830.93

V. TRUST FUND STATUS AS OF DECEMBER 31, 1973

	Ind. Acad. Sci.		Ind. Acad. Sci. Inv.		J. S. Wright Fund	
	Market Value	Carrying Value	Market Value	Carrying Value	Market Value	Carrying Value
Income Cash						
and Reserves \$	353.04	\$ 353.04	\$ 493.33	\$ 493.33	\$ 2,889.07	\$ 2,889.07
Principal Cash	362.57	362.57	25.15	25.15	212.47	212.47
Total Cash ---	\$ 715.61	\$ 715.61	\$ 518.48	\$ 518.48	\$ 3,101.54	\$ 3,101.54
Investments						
Stocks -----	\$10,286.00	\$ 9,558.48	\$ -----	\$ -----	\$642,319.50	\$264,257.47
Bonds -----	9,000.00	9,000.00	15,000.00	15,000.00	62,412.50	62,001.25
Total -----	\$19,386.00	\$18,558.48	\$15,000.00	\$15,000.00	\$704,732.00	\$326,258.72
Total Value --	\$20,101.61	\$19,274.09	\$15,518.48	\$15,518.48	\$707,833.54	\$329,360.26

VI. NOTES

Transfer to Administered Accounts:

By mail ballot, members of the budget committee approved an additional \$200.00 transfer to the Junior Academy Account to cover travel expenses during the establishment of regional units and other reorganization of the Junior Academy.

Membership Dues:

According to the Treasurer's records, the current status may be summarized as follows:

- 1016 paid, emeritus, life, honorary and paid club members
- 142 on file from 1972, but not yet paid for 1973
- 110 new members for 1973 (included in above totals)
- 22 previous members reinstated during 1973 (included in above totals)
- 108 members and clubs dropped for nonpayment of 1972 dues

Dues Structure for 1973:

- \$6.00 for regular and club memberships
- 3.00 for student memberships
- 8.00 for family memberships
- 1.00 initiation and reinstatement fee for regular, club or student membership
- 2.00 initiation and reinstatement fee for family memberships

Savings:

The treasurer, from the total assets of both Academy and Administered accounts, has maintained sufficient funds in the checking account to pay current bills throughout the year; the remaining funds have been invested in savings certificates.

Certificates redeemed in 1973

1. \$4,465.07 invested at 5.75% April 1970; April 1973 redemption value \$5,306.91
2. \$6,000.00 invested at 6.00% April 1970; April 1973 redemption value \$7,183.78

Certificates Current

1. (FWSL) \$5,000.00 invested at 6.00% April 1972; current value \$5,536.06; maturity at April 1974
2. (GWSL) \$5,000.00 invested at 6.00% April 1973; current value \$5,229.25; maturity at April 1975
3. (GWSL) \$7,000.00 invested at 6.00% April 1973; current value \$7,322.20; maturity at April 1975

Reprints:

Reprint charges to authors for Vol. 81 are being collected. Charges to three authors are outstanding for a total of \$167.70 giving a net profit to the Academy of \$185.46 in excess of printing costs.

Research:

Grants totalling \$5,441.40 were made to R. N. PHEIFER (Geology), H. R. AINSCOUGH (Geography and Geology), J. O. WHITAKER, JR. (Life Sciences), A. J. RUDMAN (Geology), G. M. HUITINK (Chemistry), A. RAVINDRAN (Industrial Engineering), J. W. REISING (Biology), W. H. WELCH (Botany), T. R. WEST (Geosciences), G. B. WILLIAMSON (Zoology), and W. T. ANDERSON, JR. (High School Science Club).

Attorney Fees:

Ice, Miller, Donadio & Ryan of Indianapolis have been representing the Academy in clarification of our tax-exemption status. The Academy was informed last year by the Internal Revenue Service and by the State of Indiana of favorable classifications, but a listing of exempt organizations published by the IRS in January did not include the Academy. The Academy will be included in supplemental printings. The Academy is currently seeking information on reprints and roles of various publications. The executive committee voted at the Fall Meeting to delay the reimbursement of \$4,226.87 for attorney fees to the Academy operating funds from the J. W. Wright fund until these funds are needed for operating expenses.

Publications:

Sales include \$30.00 for *Proceedings* and \$428.00 for *Monographs* with charges for 9 *Monographs* outstanding. The actual cost for publishing Vol. 81 of the *Proceedings* was \$10,146.36 of which the State of Indiana paid \$4,000.00 leaving a balance of \$6,146.36 to be paid by the Academy. *Monograph* #3 was published for a total cost of \$12,077.00.

HEW Grant (OEG-0-72-5014), Environmental Education Program:

	Honoraria	Travel	Textbooks	Materials	Total
Clinton -----	\$ 700.00	\$130.20	-----	\$ 74.06	\$ 904.26
Peru -----	795.00	166.70	-----	98.15	1,059.85
Versailles -----	800.00	210.68	-----	102.01	1,112.69
Jasper -----	850.00	113.29	-----	100.00	1,063.29
General -----	100.00	9.20	\$437.85	33.36	580.41
Total -----	\$3,245.00	\$630.07	\$437.85	\$407.58	\$4,720.50
\$6,100.00 received from HEW					
4,720.50 expended					
\$1,379.50 balance refunded to HEW					

VII. BUDGET FOR 1974

The following budget was approved by the Budget Committee at their meeting at the Indiana State Library, Indianapolis, on December 1, 1973:

Anticipated Income		
Dues, Initiation and Reinstatement fees -----		\$6,000.00
Interest on Savings -----		1,050.00
Reprints: Net Profit on Sales to Authors -----		150.00
		\$7,200.00
Budgeted Expenditures		
Secretary -----		\$ 650.00
Treasurer -----		275.00
General Office Supplies -----		250.00
Officer Travel, AAAS dues, etc. -----		225.00
Membership Committee -----		100.00
Transfer to Administered Accounts -----		2,650.00
Junior Academy -----	\$ 100.00	
Science and Society Committee -----	300.00	
Natural Areas Committee -----		
Library Binding -----	1,000.00	
Proceedings: Publication -----	1,000.00	
Proceedings: Mailing -----	250.00	
President's Fund -----		100.00
Newsletter -----		225.00
Speaker of the Year -----		550.00
Honorarium -----	500.00	
Administrative Expenses -----	50.00	
Program Committee -----		750.00
Publications Editor's Expenses -----		500.00
Youth Activities -----		50.00
Public Relations -----		50.00
Section Chairman Expenses -----		150.00
CPA Fees for tax return preparation, etc. -----		600.00
		\$7,125.00

Respectfully submitted:

Clyde Metz, Treasurer

December 31, 1973

We, the undersigned, have audited the Treasurer's records for the Indiana Academy of Science for the year 1973 and have found them to be accurate and in order.

CURTIS A. DHONAU

ROBERT E. DOLPHIN

February, 1974

THE INDIANA JUNIOR ACADEMY OF SCIENCE

The 41st Annual Meeting

The Forty-first annual meeting of the Junior Academy of Science was held October 27 at Lilly Hall, Indiana Central College, at 8:00 AM. Those that attended the meeting registered at 8:00 AM. Fifty-seven people were present from various high schools throughout the state. At 8:30 AM there was a rap session with the following scientists:

DR. WILLIAM R. GOMMEL, Indiana Central College

Soil and Atmospheric Sciences

DR. WILMER K. FIFE, Indiana Univ.-Purdue Univ., Indianapolis

Chemistry

DR. JAMES CLARK, State Office Building

Entomology

DR. JAMES BROWN, Indiana Univ.-Purdue Univ., Indianapolis

Geology

DR. JOHN SWEZ, Indiana State University

Biophysics and Computer Science

DR. E. M. VONDRAK, Indiana Central College

Physics

Meanwhile, a council meeting was in session.

The meeting was called to order at 10:30 AM by President Laura Fisher. Dr. Borden, professor at Indiana Central College, gave a warm welcome and Dr. Schmelz, President-elect of the Indiana Senior Academy of Science, was introduced. Next, Dr. William Hopp, President of the Indiana Academy of Science and Professor of Zoology at Indiana State University, gave a presentation on snakes entitled "Dr. Hopp and Friends". The meeting was adjourned at 12:00 NOON for a lunch break.

At 1:15 PM the meeting resumed beginning with papers presented by the following students:

MR. CHRISTOPHER RITTER, Bloomington High School North

"The Effect of Acupuncture on the Production of 17-Hydroxycorticosteroids"

MISS LINDA RUTH OUTLAW, Roosevelt High School, Gary

"Improving Cariogenic Breakfast Cereals"

MIKE PELLETIER, New Haven High School

"Analysis of Aldehydes in the Cellulose Distillate"

MR. KEVIN L. POORMAN, Terre Haute North Vigo High School

"Polygraph Interpretation of the Stimulus-Response in Selected Plants"

JIM PAVELKA, Hobart Science Club

"Extra Sensory Perception"

The minutes were read by Karen Brugge, Secretary, and were approved as read. There was no old business discussed. For the new business Ray Lichtenhan, chairman of a committee to write a constitution, presented a new constitution and stated that the adoption of the constitution with revisions made, would be voted upon at the next meeting.

There was a discussion on electing new officers for the coming year. A motion was made that the officers be elected in the same manner as in

the previous meeting, but the motion was withdrawn. Another motion was made that there be no elections and that the present officers remain as the officers. They are: President—Laura Fisher, Vice-President—Jonathan Dean, and Secretary—Karen Brugge. The motion was seconded and carried.

Dr. Lawrence E. Poorman, Department of Physics, Indiana State University, announced the Best Boy and Girl Scientists who are Mike Pelletier from New Haven High School, New Haven, and Laura Fisher from Lew Wallace High School, Gary. The meeting was adjourned at 3:00 PM by President Laura Fisher.

Secretary, KAREN BRUGGE

DIRECTOR'S REPORT

The Indiana Junior Academy of Science Council, meeting in Indianapolis July 25, 1973, to revitalize the program of the Academy, agreed to set up eight regional centers around the state. Each region will have a director who in turn will agree to serve on the council for the state organization. Each regional director will choose a student director to act as regional liaison between club members and the regional director. The eight student directors will be encouraged to attend the state council meeting annually held at the time of the Indiana Academy of Science meetings.

REGION	COUNTIES	NAME(S)
I	Lake, Porter, LaPorte, St. Joseph, Marshall, Starke, Newton, Jasper, Pulaski, Fulton, Benton	DR. MARY J. PETTERSON Hammond Morton MR. LEE MOSS Gary Wallace
II	Elkhart, LaGrange, Steuben, DeKalb, Noble, Kosciusko, Whitley, Allen, Wabash, Huntington, Wells and Adams	MR. KEITH HUNNINGS New Haven High School
III	White, Cass, Miami, Howard, Carroll, Tippecanoe, Clinton and Tipton	ROY APFLEGATE Tentative: Harrison High School Lafayette, IN
IV	Grant, Blackford, Jay, Madison, Randolph, Delaware, Henry & Wayne	DR. KEITH AULT Ball State University Chemistry Department Muncie, IN 47306
V	Warren, Fountain, Montgomery, Putnam, Parke, Vermillion, Vigo, Clay, Owen, Sullivan and Greene	MR. STEVE THOMPSON Crawfordsville High School
VI	Boone, Hamilton, Hendricks, Marion, Hancock, Morgan, Johnson, Shelby, Monroe, Brown, Bartholomew, Rush, Decatur, Fayette, Union and Franklin	MR. ELLIOT KOYANOI MR. GEORGE IUGINBILL Bloomington H.S., North
VII	Knox, Daviess, Martin, Gibson, Pike, Dubois, Posey, Vanderburgh, Warrick and Spencer	MR. JAMES SCHWENGEL Harrison High School Evansville, IN
VIII	Lawrence, Jackson, Jennings, Ripley, Dearborn, Ohio, Switzerland, Jefferson, Scott, Washington, Orange, Crawford, Harrison, Floyd, Clark, Perry	DR. J. MOODY Indiana University, Southeast New Albany, IN

Mr. Ray Lichtenhan has agreed to serve as state student director. Ray is a past president of Indiana Junior Academy of Science and is now a student at Wabash College. He also is chairman of a constitution committee and will have a constitution ready for review at the October meeting.

In essence, the State of Indiana has been arbitrarily divided into eight regional areas which will better serve students as science club members in their association with the Indiana Academy of Science.

Each region will have a director and a student director. These two persons will coordinate regional programs and assist science clubs in becoming members or continuing worthy activities.

Science Club sponsors and officers consult with regional directors on matters of state-wide concern.

The regional directors will constitute the Junior Academy Council and the student regional directors will constitute the student advisory council.

BIOLOGICAL SURVEY COMMITTEE

JACK R. MUNSEE, Chairman, Indiana State University

Publications of 1971, 1972, and 1973

Dealing with the Biota of Indiana

- Musci:** WELCH, W. H. 1973. Studies in Indiana bryophytes XV. Proc. Indiana Acad. Sci. 82:123-127.
- . 1972. Studies in Indiana bryophytes XIV. Proc. Indiana Acad. Sci. 81:284-289.
- Tracheophyta:** BROOKS, G. M., and T. R. MERTENS. 1972. A biosystematic study of *Polygonum ramosissimum* and *Polygonum tenue*. Proc. Indiana Acad. Sci. 81:277-283.
- CHANEY, W. R., and A. C. LEOPOLD. 1972. Enhancement of twig abscission in white oak by ethephon, Can. J. Forest. Res. 2:492-495.
- HELMS, RONALD L., and M. T. JACKSON. 1973. Effects of ground fire on spring wildflower populations of oak-hickory forests. Proc. Indiana Acad. Sci. 82:181-182.
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- SCHMELZ, D. V., and D. L. HODDE. 1971. The James Bird Woods: An old-growth oak-hickory remnant in Harrison County, Indiana. Proc. Indiana Acad. Sci. 80:215-219.
- Protozoa:** TAMAR, H. 1971. *Mesodinium fimbriatum* Stokes, 1887, a ciliate with bifurcated and barbed cirri. Acta Protozoologica 9:209-222.
- . 1973. Observations on *Askenasia volvox* (Claparède and Lachmann, 1859). J. Protozool. 20:46-50.
- Platyhelminthes:** ADALIS, D. 1971. A study of cecal helminths of the house mouse, *Mus musculus* L., in Delaware County, Indiana. Proc. Indiana Acad. Sci. 80:485-488.
- Arachnida:** MINTON, S. A. JR. 1972. Poisonous spiders of Indiana and a report of a bite by *Chiracanthium mildei*. Indiana State Med. Assoc. 65:425-426.
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- Crustacea:** EBERLY, WILLIAM R. 1971. New records for *Craspedacusta* in Indiana. Proc. Indiana Acad. Sci. 80:178-179.
- . 1971. The conchostracan *Lynceus* (Crustacea) found in Indiana. Proc. Indiana Acad. Sci. 80:175-176.
- Insecta:** BETRAS, S., and R. E. SIVERLY. 1972. Preliminary investigation of the effects of three hormonomimetic compounds on larvae of *Culex pipiens pipiens* (L.) Proc. Indiana Acad. Sci. 81:172.

- SABATH, M. D., R. C. RICHMOND, and R. M. TORRELLA. 1973. Temperature-mediated seasonal color changes in *Drosophila putrida*. Amer. Midland Natur. 90:509-512. (*Drosophila putrida* recorded from Monroe County, Indiana.)
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- and ———. 1972. A preliminary study of autogeny and host preference of *Culex pipiens* (L.) (Northern house mosquito). Proc. Indiana Acad. Sci. 81:172-173.
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- Aves : HOEKSTRA, W., and C. M. KIRKPATRICK. 1972. The bobwhite quail of Crane Naval Ammunition Depot, Indiana—25 years of protection and plant succession. Proc. First Nat. Bobwhite Quail Symp., Okla. State Univ., Stillwater. (processed reprint 16 p.)
- KIRKPATRICK, R. D., M. ROY, G. WISE, and L. L. HARDMAN. 1972. Contents of southern Indiana wild turkey droppings. Proc. Indiana Acad. Sci. 81:165-168.

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- . 1972. Food and external parasites of *Spermophilus tridecemlineatus* in Vigo County, Indiana. J. Mammal. 53:644-648.
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- CARRICO, SUSAN. 1971. A natural landscape plan for a central Madison County deciduous forest site—general principles and specific application. M.A.E., Ball State Univ.
- DONSELMAN, HENRY M. 1973. An ecological analysis of the shrub stratum in the beech-maple forest type. M. A., Indiana State Univ. 127 p.
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- LEVENSON, JAMES B. 1973. The herbaceous stratum of the beech-maple forest: A community structure analysis. M.A., Indiana State Univ. 134 p.
- MCCLAINE, MANSON L. 1973. Site preferences and growth responses of Kentucky coffeetree, *Gymnocladus dioica* (L.) K. Koch, near the center of its range. M.A., Indiana State Univ. 105 p.
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- SHEAR, LOIS D. 1973. A biosystematic study of Queen Anne's Lace, *Daucus carota* (Linnaeus), from four different Indiana Habitats. M.A.E., Ball State Univ.
- Platyhelminthes:** BAUMAN, MALCOLM J. 1971. Helminth endoparasites of the bobwhite quail, *Colinus virginianus*, in northern Indiana. M.S., Ball State Univ.
- Amphibia:** CALDWELL, R. S. 1973. Seasonal activity of the red-backed salamander, *Plethodon cinereus*. M.A., Indiana State Univ.
- Pisces:** CLARK, DENNIS E. 1973. Morphological and ecological relationships of *Etheostoma coeruleum* and *Etheostoma spectabile* in west central Indiana. Ph.D., Indiana State Univ.
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- MILLER, WILLIAM G. 1973. Notes on the biology of the lake trout and other selected salmonids in Indiana waters of Lake Michigan in 1970. M.S., Ball State Univ.

- RHODES, RAYMOND J. 1971. The food habits of the alewife in Indiana waters of Lake Michigan in 1970. M.S., Ball State Univ.
- WEBB, DARREL A. 1973. Daily and seasonal movements and food habits of the alewife in Indiana waters of Lake Michigan near Michigan City, Indiana in 1971 and 1972. M.A., Ball State Univ.
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- MORRIS, LARRY J. 1972. A herpetological survey of the Indiana dry prairies. M.S., Ball State Univ.
- SMITH, DAVID LEE. 1971. Movements of eastern garter snakes (*Thamnophis sirtalis sirtalis*) tagged with radioactive cobalt. Ed. D., Ball State Univ.
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- Aves :
- MANNAN, WILLIAM. 1973. A comparative study of the breeding bird populations of Clifty Creek and Crooked Creek Valleys. B.A., Hanover College.
- NIEHAUS, JON J. 1972. Food items in bobwhite, *Colinus virginianus*, droppings collected on Salmonie Reservoir area in northern Indiana. M.A., Ball State Univ.
- ROY, MARSHA. 1971. Contents of southern Indiana wild turkey droppings. M.A., Ball State Univ.
- Mammalia :
- DIETZ, JAMES M. 1973. The effects of sodium deficiency, cover availability, and high temperature extremes on certain physiological parameters in confined cottontail rabbits. M.S., Purdue Univ. 68 p.
- FISH, PAUL G. 1971. *Moniliformis Clarki* in small mammals in Vigo County, Indiana. M.A., Indiana State Univ.
- HOUTCOOPER, WAYNE C. 1971. Soil and available food as factors affecting the distribution and abundance of *Peromyscus maniculatus bairdii* and *Mus musculus* in Vigo County, Indiana. M.A., Indiana State Univ.
- HUFFMAN, LLOYD D. 1972. Annotated list of mammals of Muscatatuck National Wildlife Refuge. M.A.E., Ball State Univ.
- LANDRUM, THOMAS W. 1971. Selected aspects of the ecology of the big brown bat (*Eptesicus fuscus*) in Grant County, Indiana. M.S., Ball State Univ.
- SCHACHT, HOBART E., JR. 1973. Mammals of the Salamonie Reservoir, Huntington and Wabash Counties, Indiana. M.S., Ball State Univ.
- SMITH, RONALD J. 1973. Weather in relation to behavior of confined cottontail rabbits. M.S., Purdue Univ.
- SOTALA, DENNIS J. 1972. Foods of white-tailed deer on Crane Naval Ammunition Depot, Martin County, Indiana. M.S., Purdue Univ.
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- RAINS, JOSEPH H. 1971. Macrobenthic population dynamics in Indiana waters of Lake Michigan in 1970. M.S., Ball State Univ.

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- Lichens :
- GOUGH, L. P. Oakland City College. Effect of high water on the vertical trunk distribution of epiphytic lichens on *Taxodium distichum* in southwestern Indiana.

- Tracheophyta :** BARNES, W. B., and M. T. JACKSON. Indiana Division of Nature Preserves and Indiana State Univ. Studies of old-growth forests on planosol soils in southeastern Indiana.
- CHANNEY, W. R. Purdue Univ. Impact of sulfur dioxide on physiological processes of woody plants.
- DAVIS, M. A., and G. R. PARKER. Purdue Univ. Distribution, biomass and productivity of *Hydrastis canadensis* in Bryan Nature Preserve.
- HOLLETT, BYRON P. Indiana State Univ. The role of mycorrhizae in the ecology and distribution of *Fagus grandifolia* Ehrh.
- HURLEY, RICHARD T. St. Francis College. Competitive studies with the closely related species *Dicentra canadensis* and *D. cucullaria*; *Erythronium americanum* and *E. albidum*; and *Setaria viridis* and *S. lutescens*.
- JACKSON, M. T. Indiana State Univ. Structural analyses of the herbaceous, shrub and tree strata within old-growth beech-maple dominated forests.
- JOHNSON, H. S., J. S. BERKEBILE, and G. R. PARKER. Purdue Univ. An ecological inventory of Bryan Nature Preserve. Proc. Indiana Acad. Sci. (In press).
- Coelenterata :** YOUNG, FRANK N. Indiana Univ. The Coelenterate, *Cordylophora lacustris* Allman, abundant along the east coast in brackish water, has been recorded inland from Illinois and more recently from Cleveland, Ohio. It has not yet been recorded from Indiana, but probably occurs here. Species of *Cordylophora* look something like a branching hydra with the tentacles scattered over the sides of the "head".
- Nematoda :** WHITAKER, J. O., JR., D. RUBIN, and J. MUNSEE. Indiana State Purdue Univ. Nematodes of mammals of Indiana.
- Insecta :** MUNSEE, JACK R. Indiana State Univ. Ants of the genus *Smithistruma* Brown, collected in an Indiana Stripmine (Hymenoptera: Formicidae).
- Amphibia :** WHITAKER, J. O., JR., D. RUBIN, and J. MUNSEE. Indiana State Univ., and Central State Univ., Ohio. Food habits of several species of the spade-foot toad, Genus *Scaphiopus* (Pelobatidae).
- Pisces :** WHITAKER, JOHN O., JR., Indiana State Univ. Food habits of fishes from White River at Petersburg, Indiana.
- and R. A. SCHLEUTER. Indiana State Univ. Occurrence of the crustacean parasite, *Lernaea cyprinacea*, on fishes from the White River at Petersburg, Indiana. Amer. Midland Natur. (In press).
- Aves :** LONNEY, LAWRENCE W., JR. Purdue Univ. Natural history of the white-breasted nuthatch (*Sitta carolinensis*).
- MELCHORS, MICHAEL A., and C. M. KIRKPATRICK. Purdue Univ. Migration chronology and field feeding of the fall population of the geese at Jasper-Pulaski Fish and Wildlife Area.
- MUMFORD, R. E., and C. E. KELLER. Purdue Univ. A check list of the birds of Indiana.
- SPORE, DONALD T. Purdue Univ. The birds of the Muscatatuck National Wildlife Refuge, Indiana.
- Mammalia :** HAAG, BRIAN. Hanover College. Small mammal populations in Jefferson Proving Ground and their DDT contents.
- MUMFORD, R. E., and J. O. WHITAKER, JR., Purdue Univ., and Indiana State Univ. The mammals of Indiana.

WEEKS, HARMON P., and CHARLES M. KIRKPATRICK. Purdue Univ. Adaptations of wild herbivores to salt hunger.

WHITAKER, JOHN O., JR., and W. A. MILLER. 1973. Indiana State Univ. Rabies in bats of Indiana: 1968-1972. Proc. Indiana Acad. Sci. (In press).

——— and L. L. SCHMELTZ. Indiana State Univ. Food and external parasites of the Eastern Mole, *Scalopus aquaticus*, from Indiana. Proc. Indiana Acad. Sci. (In press).

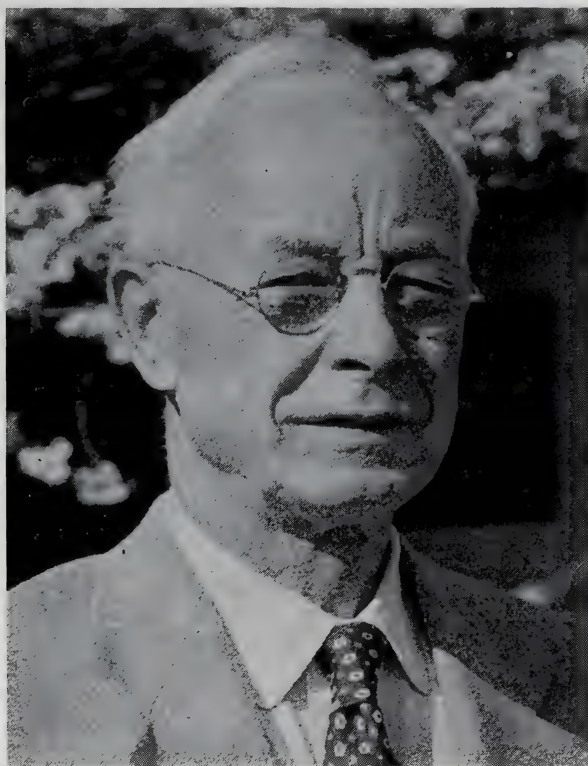
Biota:

HELMS, RONALD L. Indiana State Univ. An ecological inventory of Dobbs Park Natural Area, Terre Haute, Indiana.

NECROLOGY

FAY KENOYER DAILY, Butler University

O(TTO) B. CHRISTY



Riley, Indiana
December 15, 1883

Greenwood, Indiana
May 6, 1973

Dr. O. B. Christy, botanist, was born and died in Indiana and spent the largest part of his teaching career at Ball State University in Indiana.

He was born on a farm, December 15, 1883, at Riley, Indiana, near Terre Haute. He attended high school in Youngstown, Ohio, from 1900 to 1902 and received a diploma from Indiana State Normal in 1910. He graduated from the University of Illinois in 1916, received a Master of Science degree from Cornell in 1923 and a Doctor of Philosophy degree from Peabody College, Nashville, Tennessee, in 1936, and took additional

work at Purdue University. While at Peabody, he received the A.S. Sullivan Award for Scholarship.

Dr. Christy began teaching in the Vigo County, Indiana, rural schools in 1903 and continued until 1908. He was principal at the Prairie Creek High School from 1910 to 1913. He was also principal at Blackhawk High School from 1916 to 1917. He was an agricultural vocational teacher at Shelbyville High School from 1917 to 1918. During the summers from 1915 to 1917, he taught at Indiana State Normal. During the summers of 1922 and 1923, he taught at Cornell University and from 1933 to 1935 at Peabody College.

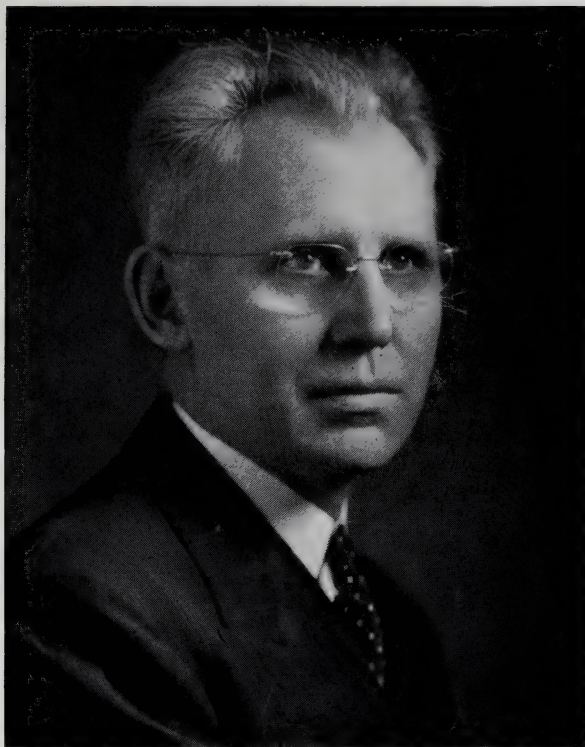
Dr. Christy became a member of the Ball State University Faculty in June 1918 and was made head of the department of botany and agriculture in 1937. He held that position until retirement in 1950, after teaching 47 years, 32 of which were spent at Ball State. Upon retirement, the faculty, staff and students presented him with a citation lauding his exemplary traits in teaching and administrative ability. He wrote a number of articles which appear in various publications including the *Proceedings of the Indiana Academy of Science*, American Tree Association publications, Procedures of the Society for Experimental Biology and Medicine, and Indiana Teachers and Farmers Exchange. One of his most rewarding achievements was the founding of Christy Woods, named in his honor by Ball State University. It is located on the campus and provides a nature study area for students of the university. Also, thousands of children and adults follow the trails through Christy Woods to enjoy the plant life and beauty of the internationally known arboretum.

Dr. Christy was very active in the Indiana Academy of Science which he joined in 1919. He was made a fellow in 1926. He served on the Membership Committee for over 10 years and the Junior Academy of Science Committee for over 15 years. He was also Program Chairman in 1940 and 1947 and served on the Invitations, Nominations and Resolutions Committees. He presented the Necrology Reports in 1955 and 1956. He was secretary of the Academy in 1948 and 1949; vice-president in 1950; and president in 1954. He was an emeritus member at his death.

Activities in other organizations include: president and vice-president of the Indiana Audubon Society; president, vice-president and honorary member of the Muncie Kiwanis Club; and president of Phi Delta Kappa. He was also a member of Kappa Delta Phi, National Education Association, American Association for the Advancement of Science, American School Garden Association, and the Indiana Nature Study Club.

After a successful and long life, Dr. Christy died at age 89 at the Westminster Village, teachers retirement home, in Greenwood, Indiana, May 6, 1973.

P(RENTICE) D(EARING) EDWARDS



Owensville, Indiana
December 21, 1895

Muncie, Indiana
February 2, 1973

Dr. P. D. Edwards, mathematician, was a native of Indiana having been born at Owensville, December 21, 1895. He was the son of Rev. J. R. Edwards and Rosalee Green Edwards. His early education was also obtained here graduating from Owensville High School in 1913, where he decided upon a teaching career. He obtained a B.S. degree at Oakland City College in 1915. He was principal of Zionsville High School from 1915 to 1917. He taught mathematics, physics, geography, music and coached the basketball team at that central Indiana school. In 1917, he accepted a position at Fort Wayne High School, but soon enlisted in the U.S. Army. He was with the 318th Engineers, Sixth Division, for 13 months. He also served the country as a civilian instructor for the army in 1946 during World War II in England and Germany, after serving with the U.S. Navy, Civil Aeronautics Administration in 1944.

After World War I, Dr. Edwards taught at Arsenal Technical High School and the Indiana University extension school in Indianapolis. He continued his education at Indiana University receiving an

A.M. degree in 1923. He was a fellow at Indiana University from 1928 to 1929 and received a Ph.D. degree in 1929. He was a graduate student and instructor at Harvard from 1924 to 1925 and also studied at the University of Chicago.

Dr. Edwards went to Ball State University as an associate professor in mathematics in 1926. He became a full professor in 1940 and the head of the mathematics department in 1952. He taught a full schedule of classes in addition to the administrative work and became a prominent educator. Recognition of his excellent teaching was given in 1968 when a residence hall in the La Follette Complex was named in his honor by Ball State University. Dr. Edwards retired in 1962. After that, he served as visiting professor at the Air Force Institute, Wright Patterson Air Force Base at Dayton, Ohio; and at Rose Hulman Institute of Technology, 1963 to 1967, before returning to Muncie to live.

Dr. Edwards joined the Indiana Academy of Science in 1927 and was elected to Fellow in 1939. He served as editor from 1941 to 1943 and from 1947 to 1948 and served on the Publication of the Proceedings Committee for 11 years. He was president of the Academy in 1952. His presidential address was on *The Role of Mathematics in Science*. He was Divisional Chairman of the Mathematics Section in 1939 and served on many committees through the years. His papers published in the *Proceedings of the Indiana Academy of Science* were primarily on mathematics education. His research interests included functional equations and the motions of double stars. He also belonged to the American Association for the Advancement of Science, National Council of Teachers in Mathematics, Phi Beta Kappa and Sigma Xi and was a member of the board of governors of the Mathematics Association of America for 3 years. He was also active as elder and deacon of the Muncie Presbyterian Church, a member of the Masonic Lodge and sponsor of the Lambda Chi Alpha social fraternity at Ball State University.

Dr. Edwards enjoyed traveling extensively in the United States of America, Mexico, Canada as well as England and Scotland.

The motto "*Nihil sine labore*", nothing without labor, expresses Dr. Edwards' personal philosophy. His diligence resulted in many positions of honor and responsibility until his death at Muncie, Indiana, February 2, 1973.

PAUL RAYMOND FOLTZ

Terre Haute, Indiana
May 27, 1943

Xuyen Province, South Vietnam
October 21, 1971

U.S. Navy Lieutenant, Paul R. Foltz, was born May 27, 1943, at Terre Haute, Indiana. He was educated there where he attended Sandison School, Woodrow Wilson Junior High School and Wiley High School. He was active in the Boy Scouts of America and earned the

Eagle Scout Award and was Vigil Honor Member of the Order of the Arrow. He later served as Scout Master at the First Baptist Church. In 1966, he graduated from Indiana State University where he received the B.S. and M.S. degrees in Life Sciences. He was a laboratory assistant for 2 years and was interested in ecology.

Upon graduation from Indiana State University, Lt. Foltz entered Officer's Candidate School and was commissioned in the U.S. Navy in 1968. He was a diving officer, qualified second class diver and salvage diver. He made three tours of duty in Vietnam. He was a member of the Officer's Christian Union and worked with Christian Service Men's Clubs. He continued his study of plants while in the service and was making a slide library of the plants he had seen.

He was decorated for his dedication to duty and awarded several medals: the Diver Officer Breast Insignia, the National Defense Service Medal, Vietnamese Service Medal, Vietnamese Campaign Medal, Purple Heart and Combat Action ribbon. He received a letter of commendation from the U.S. Department of Navy for his outstanding work.

Lt. Paul R. Foltz, at age 28, was killed on October 21, 1971. He was on the Trem Trem River in the Xuyen Province of South Vietnam when an enemy rocket attack was made on his salvage craft, bringing to a close the promising career of a well-loved and highly capable young man.

FRANK T (HOMSON) GUCKER

Philadelphia, Pennsylvania
April 8, 1900

Bloomington, Indiana
March 6, 1973

Dr. Frank T. Gucker was a research professor emeritus of Chemistry at Indiana University and formerly dean of the College of Liberal Arts and Sciences at his death in Bloomington, Indiana, March 6, 1973. He was born in Philadelphia, Pennsylvania, April 8, 1900. His college education was begun at Haverford College where he obtained an A.B. degree in 1920; was a fellow from 1920 to 1921, and received an A.M. degree in 1921. He was an Austin Fellow at Harvard from 1921 to 1922, Harris Fellow from 1923 to 1924, and received a Ph.D. degree in 1925. He was an assistant to Professor T. W. Richards from 1924 to 1925 and 1927 to 1928. He then was a National Research Council Fellow at the California Institute of Technology from 1925 to 1927. He was research chemist, ammonia division, of the E.I. du Pont de Nemours and Company from 1928 to 1929. In 1929, he went to Northwestern University as assistant professor of chemistry. He became associate professor in 1936 and full professor in 1942. Dr. Gucker left Northwestern in 1947 to come to Indiana University where he was chairman of the department of chemistry. He became dean of the College of Arts and Sciences in 1951, holding that position until 1965 when he became research professor. He retired in 1970 with emeritus status.

Dr. Gucker held many responsible positions. He was a fellow of the Carnegie Institution from 1940 to 1950. He was a member of the committee on physical chemistry and the subcommittee on fundamental constants of the National Research Council from 1951 to 1954, the committee on awards in chemistry under the Fulbright Act from 1954 to 1959, and chairman 1955 to 1959. He was consultant and member of the advisory panel in chemistry, Division of Mathematics, Physics and Engineering Sciences for the National Science Foundation from 1957 to 1960 and chairman from 1958 to 1959. He was a member of the Oakridge National Laboratory Advisory Commission on Reactor Chemistry from 1961 to 1963. He was a technical aide for a division of the National Defense Research Committee in 1941 to 1942 and Regional Councilor for the Army's Office of Ordinance Research from 1952 to 1954. In this capacity, he acted as coordinator and advisor for civilian research projects sponsored by the Office of Ordinance Research. He served on the executive committee of the American Council of Academic Deans from 1961 to 1963. In 1966, the Association of American Colleges appointed him to a 3-year term on the Commission of Liberal Learning.

Dr. Gucker had a long standing grant while at Indiana University from the National Air Pollution Control Administration for a study of the properties of aerosol gases. In addition, his research interests covered thermochemistry, precise calorimetry, specific heats, heats of dilution, densities and compressibilities of solutions of electrolytes and amino acids, photoelectronic counting and sizing of colloidal particles and the refrigerating power of two-component systems. He developed an aerosol particle counter with both wartime and peacetime applications. It could detect airborne germs, dust, moisture and radioactive particles. Dr. Gucker was the author of textbooks and articles and was associate editor of *Chemical Reviews* from 1950 to 1953.

Dr. Gucker joined the Indiana Academy of Science in 1948, a year after moving to Indiana, and was made a fellow in 1954. The papers which he presented at Academy meetings concerned education in chemistry and a calorimeter. Other organizations in which Dr. Gucker was involved were many. He was a fellow of the American Association for the Advancement of Science, member of the American Society of Testing Materials, American Chemistry Society (councilor, chairman of the council policy committee, 1959 to 1961, member of the nominations committee, secretary from 1964 to 1966), Phi Beta Kappa (president of Gamma chapter 1965 to 1966), Sigma Xi, Alpha Chi Sigma, Phi Lambda Upsilon, Presbyterian Club, and Faculty Men's Club at Indiana University.

Dr. Frank T. Gucker was almost 73 years old when he died after a distinguished career in chemical research and consulting for the government and industry.

FLOY HURLBUT

Kearney, Nebraska
April 29, 1888

Muncie, Indiana
January 2, 1973

Born of a Methodist minister and wife in Kearney, Nebraska, April 29, 1888, Dr. Floy Hurlbut, geographer, was to combine a religious and academic career.

Her college training began at John Fletcher College and she completed the A.B. degree at Taylor University in 1911. In 1912 to 1926, she served as a missionary and taught in the Foochow Women's College in South China. She returned to Fukien Province in 1947 to attend the Centenary Celebration of the Methodist Church of China.

Dr. Hurlbut continued her education after returning to the United States of America and received an A.M. and Ph.D. degree from the University of Nebraska in 1928 and 1930, respectively.

Dr. Hurlbut's earliest teaching assignment was at the Dunbar, Nebraska High School. Then she taught at the University of Nebraska before coming to Ball State University in 1931. She became a professor in 1949. Not content with only her teaching duties, she established a weather bureau about 3 years after coming to Ball State University and provided weather reports for the Muncie Evening Press and WLBC radio station. She was a meteorologist under the United States Civil Service Commission and Civil Aeronautics Authority. She also found time to teach a Bible Class at the High Street Methodist Church. In 1965, Dr. Hurlbut was honored for many years of service well done by having a residence hall in the Studebaker Complex at Ball State University named for her. She retired from Ball State in 1954 as professor emeritus of science, and became a full-time director of the Muncie Travel Service.

Dr. Hurlbut joined the Indiana Academy of Science in 1933 and was made a fellow in 1953. She was on the Program Committee in 1947, chairman of the Geology and Geography Division in 1948, served on the Resolutions Committee in 1954, and on the Fellows Committee from 1961 to 1964. She was author or co-author of several papers presented at the Academy dealing with the Far Eastern conflict; *Our Highways, an Indian Heritage*, and the *Influence of Salt in the Early Life of America*. Other publications include *The Climate of Fukien Province*, published by the Natural History Society of Fukien Christian University and the book, *The Fukienses: A Study in Human Geography*. Dr. Hurlbut was elected to Sigma Xi, Psi Chi and Sigma Delta Epsilon honorary societies and was the first woman president of Sigma Zeta, national science honorary organization. She was also a member of the American Association for the Advancement of Science.

Dr. Hurlbut's sister, Dr. Zylpha Hurlbut, also came to Indiana to become head of the department of Biology at Anderson College.

Dr. Floy Hurlbut, age 85 years, was still director of the travel agency in Muncie when she died at Ball Hospital, January 2, 1973, after a long and varied career.

FRANK DUNN KERN

Reinbeck, Iowa
June 29, 1883

State College, Pennsylvania
September 28, 1973

The first dean of the Graduate School at Pennsylvania State University and botanist, Dr. Frank D. Kern, was 90 years old when he died September 28, 1973. Born in Reinbeck, Iowa, June 29, 1883, Dr. Kern was educated at the University of Iowa receiving a B.S. degree in 1904. He received an M.S. degree from Purdue University in 1907, and a Ph.D. degree from Columbia University in 1911. He was a fellow at Columbia from 1910 to 1911. He was an assistant in animal morphology and physiology at Iowa from 1902 to 1904; special agent for the Bureau of Plant Industry, U.S. Department of Agriculture from 1904 to 1905; and assistant botanist to associate botanist at the Purdue University Experiment Station from 1905 to 1913. He was research scholar at the New York Botanical Garden from 1906 to 1908 and 1910.

Dr. Kern went to teach at Pennsylvania State University in 1913. He was professor of botany and head of the department until 1950. He became dean of the Graduate School when it was established in 1922 and held that position also until his retirement in 1950. During those years, a number of graduate programs in various fields were developed by Dr. Kern. He became an emeritus professor and dean at retirement.

Dr. Kern took a leave of absence from Penn State in 1926 to 1927 and again in 1933 to 1934 and served as acting dean of the University of Puerto Rico, Colleges of Agriculture and Engineering. He received the honorary Doctor of Science degree from the University of Puerto Rico in 1926 and also received a public instruction medal from Venezuela in 1934. He made botanical explorations in both countries and also the Dominican Republic. He was "starred" in *American Men of Science* for his distinguished research.

In addition to his research and administrative duties at Pennsylvania State University, he taught 51 courses through the years, primarily elementary botany and plant pathology.

Dr. Kern joined the Indiana Academy of Science in 1905, the year he came to Purdue University. He presented a paper at annual meetings of the Academy almost every year he was in Indiana. These were chiefly on the rust fungi, puffballs, and plant diseases—particularly crop plants. He was invited to address the general session of the Indiana Academy of Science at Purdue University, November 4, 1938, when he spoke on *The Life and Work of Joseph Charles Arthur*. He was co-author of a paper on the *History of the Arthur Herbarium at*

Purdue University given at the History of Science Section of the Indiana Academy of Science in 1961. Dr. Kern was elected a fellow in 1912 and was an emeritus member at death.

Throughout Dr. Kern's career, he was the author of numerous publications. After retirement, he published more than 20 papers and early in 1973 published a new book on cedar apple rusts, a revision of work started more than 60 years previously.

Among other organizations which Dr. Kern joined was the American Phytopathological Society of which he was vice-president in 1914. He was past president (1945) of the Mycological Society of America. He was a past vice-president of the American Association for the Advancement of Science and member of the Botanical Society of America and Torrey Botanical Club. He was a member of the division of biology and agriculture on the National Research Council from 1946 to 1950. He was elected to Sigma Xi, Gamma Sigma Delta (agriculture honorary), Phi Epsilon Phi (botany honorary) and Alpha Zeta (professional agricultural fraternity). He was elected to Phi Kappa Phi honor society of which he was national president and took an active part in the organization in various facets of its work. He was honored by the Phytopathological Society in 1958 as a charter member and as author of the first scientific paper published by that society.

Dr. Frank D. Kern had been a member of the Indiana Academy of Science for 68 years at his death even though he had moved away and had been a resident in Pennsylvania since 1913. A tribute to his loyalty!

E(ARL) T(HURSTON) MCBEE

Braymer, Missouri
July 6, 1906

Fort Lauderdale, Florida
January 2, 1973

Dr. Earl T. McBees was a chemistry faculty member at Purdue University from 1935 until his death January 2, 1973.

Born July 6, 1906, in Braymer, Missouri, Dr. McBees studied at William Jewell College and received an A.B. degree in 1929. He was an assistant in chemistry from 1927 to 1929. He then went to Purdue University receiving an M.S. degree in 1931, was a fellow from 1930 to 1935 and received a Ph.D. degree (chemistry) in 1936.

Dr. McBees held almost 100 patents on chemical processes and products, some of which were responsible for the development of commercial plants which produced chlorinated chemicals in the manufacture of agricultural chemicals, pesticides, a fire retardant, plastics, etc. He was chairman of the board and president of the Great Lakes Chemical Corporation at Lafayette; president of the Arkansas Chemical and Bromet Company at Magnolia, Arkansas; and was also executive vice-president of the Great Lakes Natural Gas Company. This was in addition to his service on the faculty at Purdue University where

he began teaching in 1935 while still working on his graduate training. He became a full professor in 1943, was head of the department of chemistry from 1949 to 1967 when he was named Shreve professor of industrial chemistry. He held this title at his death.

He was a civilian with the U.S. Army, U.S. Army Air Force, and U.S. Navy. In 1945, he received a certificate of public service from the United States of America War Department and Office of Science Research and Development for his contribution to the Manhattan Project, the atom bomb development program, in devising a process for a satisfactory coolant. Papers by Dr. McBee and associates on recent advances in fluorine chemistry were presented at a symposium held by the American Chemical Society in Chicago, September, 1946. A paper in the *Proceedings of the Indiana Academy of Science* (Volume 56) discusses some of these. Dr. McBee received further honors including the Modern Pioneer Award from the National Association of Manufacturers, the rank of Fellow from the American Association for the Advancement of Science, the American Institute of Chemistry and the New York Academy of Science. He was also elected Director of the American Institute of Chemistry in 1970 and received a Sigma Xi Research Award.

Dr. McBee joined the Indiana Academy of Science in 1951, was made a Fellow in 1954, was Chairman of the Chemistry Division in 1958 and served on the Resolutions Committee in 1959. He was senior author of about a dozen papers delivered at annual paper sessions during the 1950's and 1960's. His research interests covered organic halides, pharmaceuticals, synthetic fibers and derivatives of natural gas hydrocarbons.

Dr. Earl T. McBee died suddenly while on vacation at Fort Lauderdale, Florida. He was 66 years of age.

CHARLES S(TEPHEN) MORRIS

Hutchison, Kansas
August 5, 1892

LaVerne, California
April 12, 1973

Dr. Charles S. Morris died April 12, 1973, in La Verne, California, where he had moved after retirement. He was a professor emeritus of physics at Manchester College, North Manchester, Indiana.

Dr. Morris was born in Hutchison, Kansas, August 5, 1892, but was brought to Indiana when only 6 months old. He attended rural grade school near Peru, Indiana, and high school at Nead, Indiana, a few miles southwest of Peru. The influence of Mr. Tom Shively, a stimulating high school teacher, probably was responsible for the selection of physics as a career by Dr. Morris.

Dr. Morris received an A.B. degree from Manchester College in 1913, an A.M. degree from Ohio State University in 1915 and also a

Ph.D. degree in 1930. Several summers were also spent in study at the University of Chicago.

Dr. Morris began teaching in elementary schools for a year. From 1913 to 1914, he taught physics and chemistry at Blue Ridge College. He was an assistant in physics at Ohio State University from 1914 to 1915. From 1915 to 1917, he was head of the department of physics and mathematics at Mount Morris College. He was professor of mathematics and physics at McPherson College from 1917 to 1926. He became professor of physics and head of the department at Manchester College, North Manchester, Indiana, in 1926, teaching both physics and astronomy. He published a laboratory manual in general college physics (Edwards Brothers Lithoprint). He also became known not only for his scholarship in science but also his quiet work in religion. His interest in astronomy involved the contribution it could make to expanding personal experiences. In 1959, Dr. Morris received a Distinguished Service Certificate from the General Brotherhood Board (Christian Education Commission) for his 45 years of service (33 of which were at Manchester College) to 4 colleges of the Church of the Brethren. This was in recognition of his long, able, dedicated career. Construction on the Charles S. Morris Observatory, being built in his honor, was begun at Manchester College, August, 1973, and is planned for completion by 1974. Friends and former students contributed to the fund for the structure.

For several years, significant grants from the National Science Foundation and Research Corporation were given for his research in gamma ray spectroscopy. He was also interested in the Raman effect in organic liquids. He became professor emeritus in 1962.

Dr. Morris joined the Indiana Academy of Science in 1935 and was honored as fellow in 1961. He served as Chairman of the Physics Division in 1960 and was also on the Program Committee that year. He was appointed to the Fellows Committee in 1964. He presented a paper at an annual fall meeting on *Physics Research in a Small Institution*.

Other organizations to which he belonged were: the American Association for the Advancement of Science, the American Association of Physics Teachers, American Institute of Physics, Indiana Association of Physics Teachers, Sigma Xi and Sigma Pi Sigma. He was also an elder, Sunday school superintendent and member of boards in the Church of the Brethren and belonged to the Kiwanis Club.

Dr. Morris traveled widely over the United States of America including Alaska, parts of Mexico and Cuba. He visited the physics departments of most of the leading universities and prominent observatories in the United States. He did metal shop work as a hobby, and for relaxation, visited with friends and former students who came from many parts of the country to visit with him. He retained a personal interest in the achievements of his students even after retirement and was highly regarded by them.

Dr. Charles S. Morris was 80 years old at his death. His accomplishments attest to his long life and high standards of achievement.

ORRIN HAROLD SMITH

Iveyville, Iowa
September 1, 1884

Everett, Washington
September 12, 1973

Dr. Orrin Harold Smith was an emeritus professor of physics from DePauw University at his death and nationally recognized for his exceptionally good educational methods.

Born in Iveyville, Iowa, September 1, 1884, Dr. Smith attended a one room rural school in Corning, Iowa. He received an A.B. degree from Knox College, Galesburg, Illinois, in 1908 and an honorary Sc.D. degree in 1961. Dr. Aladine Longden of that university is credited with first interesting Dr. Smith in physics while a student of Dr. Longden. He obtained an A.M. degree from the University of Illinois in 1909 and a Ph.D. degree in 1914.

Dr. Smith taught high school in Illinois from 1909 to 1910 and was an assistant in physics at the University of Illinois from 1910 to 1914. He was a professor at Cornell College of Mount Vernon, Iowa, from 1914 to 1925. As a visiting professor sponsored by the Rockefeller Foundation, Dr. Smith taught at Southeastern University, Nanking, from 1922 to 1923; Lawrence College, 1952 to 1953. Sponsored by the Hill Family Foundation, he was visiting teacher at Macalester College and Hamline from 1953 to 1954 and Grinnell College from 1954 to 1956. Sponsored by the John Hay Whitney Foundation, he was visiting teacher at Kalamazoo College in 1957 to 1958.

Dr. Smith received emeritus rank from DePauw University in 1952, but was still teaching three classes a week in March, 1959, when an article appeared in the *DePauw Alumnus* about his receiving the Golden Key Award at the American Association of School Administrators convention in Atlantic City. He was also featured in a story by *Parade Magazine* (Feb. 15, 1959) after receiving the Golden Key Award. Two people are honored annually—a citizen who has contributed significantly to the national welfare and the teacher whom the citizen deems to have influenced his career the most. Dr. Lee DuBridge, President of the California Institute of Technology and later science advisor to President Nixon was the Golden Key recipient who chose Dr. Smith as co-recipient of the honor, Dr. DuBridge wrote a tribute to Dr. Smith for the *DePauw Alumnus* (April, 1959) describing his genius for stimulating teaching. Dr. Smith also received the Oersted Medal in 1950 from the American Association of Physics Teachers as the outstanding physics teacher of the year. In 1951, he was chosen by students as DePauw's best teacher. Secondary to Dr. Smith's interest in teaching and assisting students toward research careers was Dr. Smith's own research activities on retrograde rays from the cold cathode.

Dr. O. H. Smith joined the Indiana Academy of Science in 1925 and was made a fellow in 1935. He was Chairman of the Physics Section in 1942 (no meeting) and 1943. He was made an emeritus member. Dr. Smith also was a member of the American Association

for the Advancement of Science, American Association of Physics Teachers, and Phi Beta Kappa.

Dr. O. H. Smith died September 12, 1973, at 89 years of age. He was living at Everett, Washington, where memorial services were held as well as at Greencastle, Indiana, where he was buried.

NEW MEMBERS FOR 1973

The following list contains the names and addresses of all new members who joined during 1973. The letter(s) following the address indicates the Section(s) of the Academy in which the member has indicated his major interest, according to the following code:

A—Anthropology	N—Engineering
B—Botany	O—Cell Biology
C—Chemistry	P—Physics
D—Science Education	R—Microbiology and Molecular Biology
E—Entomology	S—Soil Science
G—Geology and Geography	T—Plant Taxonomy
H—History of Science	Y—Psychology
L—Ecology	Z—Zoology
M—Mathematics	

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 MRS. ROSALIE J. AKEY, R. R. 1, Mooreland, IN 47360, BLD
 DR. EUGENE D. ALBRECHT, Biological Science Section, Purdue Univ., Fort Wayne, IN 46805, ZRO
 DR. WALTER L. BALCAVAGE, Medical Education, Holmstedt Hall, Indiana State Univ., Terre Haute, IN 47809, RCO
 DR. DWIGHT B. BEERY, Physics Dept., Manchester College, North Manchester, IN 46962, PLD
 DR. BENJAMIN BECKER, Purdue Univ. Fort Wayne, IN 46805, ROC
 DR. WILLIAM J. BEGUE, Eli Lilly and Co., Greenfield Lab., P. O. Box 708, Greenfield, IN 46140, RC
 DR. PAUL L. BOCK, Dept. Chemistry, Ball State Univ., Muncie, IN 47306, CDH
 MR. KENNETH LEON BOWERS, R. R. 8, Box 237, Muncie, IN 47302, PNH
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 MR. ROBERT L. BURTCH, 329 N. Van Buren, Batavia, IL 60510, D
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 MR. PHILLIP CASERATTI, Dept. Geology, Indiana Univ., Bloomington, IN 40471, GPN
 MR. ROBERT K. CAUDELL, Science Teaching Center, Indiana State Univ., Terre Haute, IN 47809, DLE
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 DR. JAMES R. CURRY, Franklin College, Franklin, IN 46131, ZL
 MRS. J. MCCARTHY DAVIS, University Apts., W. 13, Bloomington, IN 47401, AZR
 DR. DON B. DEYOUNG, Physical Science, Grace College, Winona Lake, IN, PGN
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- MR. RICHARD H. GILBERT, 727 W. Ralston Rd., Indianapolis, IN 46217, GTS
- DR. CARL W. GODZESKI, Eli Lilly Co., Indianapolis, IN 46206, ORC
- DR. LARRY P. GOUGH, Biology Dept., Oakland City College, Oakland, IN 47660, LBT
- MR. TERRY F. GRAY, Bionucleonics Dept., Purdue Univ., W. Lafayette, IN 47907, LSD
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- DR. JERRY HAMELINK, Dept. For. and Cons., Purdue Univ., W. Lafayette, IN 47906, LZC
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- MISS NANCY HENDRICKS, Radio TV Dept., Public Schools, 931 Fletcher Ave., Indianapolis, IN 46203, AGL
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- MR. RONALD L. KIRKPATRICK, P. O. Box 2083, Kokomo, IN 46901, ZRD
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PART 2

ADDRESSES
AND
CONTRIBUTED
PAPERS

Indianapolis, Indiana
October 25-26, 1973

PRESIDENTIAL ADDRESS

The address, "Snakes Alive" was presented by retiring president, DR. WILLIAM B. HOPP, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809, at the annual Fall Meeting dinner at the Indiana Central College Dining Hall, Indiana Central College, Indianapolis, Indiana, on Friday, October 26, 1973.

PRESIDENTIAL ADDRESS

Snakes Alive

WILLIAM B. HOPP, Department of Life Sciences
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It would seem that I was predestined to be a zoologist, since I have always been interested in animals. Most of my earlier memories are of animals—a stuffed buffalo in a museum, a live tiger in a zoo, a cecropia moth on the side of a shed. Of all the animals, I was (and still am) most intrigued by those feared, misunderstood and yet fascinating creatures, the snakes. With the possible exception of the monkey house, the reptile house draws the greatest crowd at a zoo. The average person seems to feel about snakes in the same way the late W. C. Fields was reputed to feel about women: he said that, to him, a woman was like an elephant—he liked to look at one, but he didn't want one of his own! Frankly, snakes are not particularly good as pets, since, although most of them will become quite placid and accustomed to handling in captivity, they are not in the least demonstrative, nor do they generally show any signs of recognizing individuals. However, as subjects of observation and study, snakes are particularly interesting.

Snakes demonstrate the basic characteristics of the reptiles, in that they are air-breathing, terrestrial, scaly-skinned, basically oviparous, poikilothermic animals. They share the order Squamata with the lizards, from which the snakes are probably derived. In general, the snakes may be distinguished from the lizards by the absence of limbs, lack of external ear-openings and the lack of functional eyelids. Of course, as is common in most biological studies, exceptions are the rule. For instance, limbs are not present in any of the snakes, but a rudimentary pelvic girdle, associated with a pair of small spurs located on either side of the vent, is found among the Boidae. No snake has external ear-openings, but then neither do the earless lizards of the genus *Holbrookia*. And well-known to herpetologists are the legless lizards (or "glass snakes"—so-called because of their tendency, in common with many other lizards, of dropping their tails in emergencies). No snake has movable eyelids, their eyes being protected by transparent scales, while lizards, as a group have movable eyelids. An exception is seen among the African chameleons, in which the eyelids are fused together, leaving a little permanently-open "port-hole" over the pupil, protected by a transparent scale.

There are over 2,000 species of snakes found throughout the tropical and temperate regions of the world (except for Hawaii, New Zealand and, of course, Ireland). Since the snakes are poikilothermic ("cold-blooded"), their temperature varies with the environmental tempera-

ture. Snakes decrease in numbers in the colder regions of their range and are entirely absent in the more frigid regions of the world. Since no energy is required to maintain a constant temperature (exception: female pythons coil around their clutch of eggs and raise their body temperature a few degrees over that of the environment), snakes are able to survive with relatively fewer feedings. Once a week or even less is quite adequate. All snakes are carnivorous (for once, no exceptions are known), swallowing the prey whole. A snake has plenty of small, thorn-like recurved teeth (typically, four rows of upper teeth and two rows of lower teeth) that are designed for grasping and holding rather than chewing. The bones of the skull and jaws are connected by elastic ligaments in such a way that a snake can swallow an animal several times larger than its own head. The prey (some species prefer warm-blooded forms, some cold-blooded, while others will take either) is detected by sight, smell or, in the case of the pit vipers and some other species, by heat-sensitive receptors. The prey is then subdued by being seized by the jaws and engulfed (a garter snake with an earthworm), by constriction (a rat snake with a mouse), or by the injection of poison (a rattlesnake with a rabbit). Incidentally, there is no truth in the idea that a snake will eat only prey that it has killed—most of our snakes in captivity are fed dead animals (many thawed out after being stored in a deep-freeze).

The poison of venomous snakes is used primarily in subduing prey (it also aids in the digestive process) rather than as a defensive mechanism. The venom itself is modified saliva, delivered from the glands by way of ducts to the paired fangs. The fangs of the vipers, whose venom is primarily haemotoxic, are long, hollow and fold backward against the roof of the mouth, while the fangs of the cobras and their relatives, whose venom is primarily neurotoxic, are smaller, grooved and permanently erect. The fangs, in common with snake teeth in general, are regularly shed and replaced by new ones. The dangerously-poisonous snakes of continental United States include copperheads, cottonmouths, a number of species of rattlesnakes and coral snakes. The first three are vipers (pit vipers), while the coral snake is related to the cobras. Indiana supports two species of rattlesnakes (*Crotalus horridus* and *Sistrurus catenatus*) and copperheads (*Agkistrodon contortrix*). No coral snakes nor cottonmouths (despite almost universal opinion to the contrary) have ever been found as native populations in Indiana. It is necessary to make this qualifying statement, since even more exotic forms (boa constrictors, anacondas, etc.) are occasionally found as escapees or releases of captive specimens.

Since they do not possess external ear openings, it is doubtful if snakes can hear air-borne sounds, but they are definitely sensitive to vibrations of surfaces with which they are in contact. In other words, the traditional flute-playing Indian snake charmer is attracting the cobra by swaying his body rather than by his flute music. Snakes do have functional eyes, except for some of the burrowing forms in which the eyes are more or less degenerate. The pupils are round, in general, in those species that prowl by day and elliptical in the

night-prowlers (which includes the pit vipers). The sense of sight is, in any case, secondary to the sense of smell. The nasal cavities may be involved in the usual way, but the forked tongue, which can convey odorous particles to two tiny structures (Jacobson's organ) in the roof of the mouth which are an extremely sensitive means of detecting air-borne particles as well as similar particles from surfaces, is most important in such functions as sex recognition, trailing prey and recognizing food. The delicate tongue, of course, also serves as a sensitive feeler.

The elongate body of a snake is remarkably flexible, due to the great number of vertebrae (several hundred, as a rule). A pair of ribs is associated with each of the vertebrae, except for those in the neck and the tail. The viscera are elongate and linear in arrangement, with the left lung being either much smaller or absent (except for the Boidae, which have well-developed paired lungs). The most common method of locomotion in snakes is accomplished by undulating the body in S-curves, with the outer surfaces of the curves serving as pushing points. An exaggeration of this technique is seen in the side-winding locomotion of some desert species. Heavy-bodied snakes may also move in a straight line by expansion and contraction of the belly surface, with the over-lapping belly scales moving in wave-like ripples while pressing against the ground surface. Snakes are not capable of great speeds, despite stories frequently told. The fastest racers have been clocked at only three and a half miles an hour, and that in short spurts only. Many snakes regularly climb shrubs and trees, and all snakes seem to be able to swim if placed in water. Of course, some species stay in or near the water most of the time, and the sea snakes, which are incapable of making any progress on land, never leave the water.

The majority of snakes are oviparous, and, with few exceptions (female pythons, as mentioned before), the eggs are deposited in a suitable medium (rotting wood, moist soil, etc.) and left without any further care. Some snakes (water snakes, garter snakes, pit vipers, boa constrictors and others) are ovoviviparous, in that the fully-formed eggs are retained within the body of the mother until development is complete. The presence of fully-developed, active young in the ruptured body of a slaughtered female snake is undoubtedly responsible, at least in part, for the belief that a mother snake will swallow her young to protect them. The sight of a large cannibalistic snake, such as a king snake or a black racer, in the process of swallowing a smaller snake is another possible basis for this superstition. The copulatory organ of a male snake is bifurcated and is withdrawn into a sac at the base of the tail. The extrusion of this structure due to heat has given rise to another superstition, namely that a snake will "grow legs" if it is thrown into a fire. Snakes are the subjects of many other interesting superstitions: a snake will avenge the death of its mate (snakes do not form permanent alliances); snakes will suckle cows (Ha! With all those sharp teeth?); hoop snakes have a poisonous fang at the tip of the tail (there are the mud snakes of the southern states that use

a spinous tail tip to hold down slippery salamanders while dining on them); a snake won't die until sundown (great innate vitality, but sundown has nothing to do with its termination); and many others.

Records are always fascinating. The longest snake ever accurately measured seems to be a reticulated python—about 35 feet (just try to accurately measure a living snake that size!). There are unsubstantiated stories of anacondas exceeding that length, but approximately 25 feet seems to be the greatest recorded length of an anaconda. The longest poisonous snake? The king cobra, with a maximum length of about 17 feet wins hands down. The most poisonous snake? Probably the Australian tiger snake, whose venom is rated as the most toxic—drop for drop—of any known species of venomous snake.

This brief, incomplete and possibly more or less inaccurate account of reptilian facts and fables was illustrated by several living specimens (including a legless lizard, several species of rat snakes and a boa constrictor named Alexander) and colored slides, particularly of poisonous snakes.

ANTHROPOLOGY

Chairman: JOHN M. HARTMAN, Indianapolis, Indiana 46200

JACK M. WHITEHEAD, Department of Anthropology,
Ball State University, Muncie, Indiana 47306
was elected Chairman for 1974

ABSTRACTS

Ahuili: A Rite of Reversal among the Eastern Nahua of the Huasteca Region of Northern Veracruz, Mexico. PAUL J. PROVOST, Department of Anthropology, Indiana University, Bloomington, Indiana 47401.—A calendrical ritual that takes place among the Nahua Indians of the Huasteca Region of Northern Veracruz was reported. An ethnographic description of the Nahua was based upon 12 months of anthropological fieldwork recently completed among them by the author. The report was presented in three parts. The first was a brief ethnographic description of the basic elements of Nahua culture and social organization, and included the central features or principles of behavior that form the pattern of Nahua culture. The second consisted of an account of a ceremony or ritual, called *Ahuili*, including how the ritual is performed and how it serves to reverse the normal order of daily life and the basic principles of the cultural order. The final part was a discussion of the function and significance that this rite of cultural reversal has for Nahua culture, as well as for culture theory in general.

Ceramics of the Multi-Component Farrand Site, Vigo County, Indiana. ROBERT E. PACE and GARY APFELSTADT, Department of Anthropology, Indiana State University, Terre Haute, Indiana 47809.—Salvage excavation around a commercial gravel pit has recovered information on a multi-component village site near the Greenfield Bayou in southwest Vigo County. Ceramic analyses have identified Early, Middle and Late Woodland components, although the major occupation was by Indians of the Mississippian Vincennes Culture. Woodland ceramics are more closely related to those known to the north and west. They include Marion Thick, Havana Tradition and Albee Culture sherds. Vincennes Culture sherds frequently combine Woodland and Mississippian features. Carbon-14 dates identify early Vincennes refuse pits from around A.D. 800, and later ones containing carbonized corn and beans, around A.D. 1100.

Cultural Marginality of the Alto Caquetá. GARY L. BROUILLARD, Department of Anthropology, Indiana University, Bloomington, Indiana 47401.—Recent investigations in the Alto Caquetá drainage (Colombia) provide data suggesting that Steward's classification of the northwest Amazon as a distinct sub-area of the Tropical Forest has considerable time depth. Ceramics recovered from 23 sites during the summer of 1973 show regional diversity within a generalized tradition which has little similarity to known Amazonian ceramic complexes. Ceramics of

the Alto Caquetá are predominantly decorated by plastic techniques which emphasize angular design elements. A very small amount of bichrome pottery is also present at three sites. In view of the geographical proximity of the Alto Caquetá to the Rio Napo and the central Amazon, the lack of ceramics belonging to the polychrome tradition suggests that the area was marginal to at least some of the major influences which shaped Tropical Forest cultures.

An Argument for the Use of Probability Testing in Defining Vegetation Zones in Archaeological Reconstructions. VAN A. REIDHEAD, Glenn A. Black Laboratory of Archaeology, Indiana University, Bloomington, Indiana 47401 and JOSEPH E. SCOTT, Department of Sociology, Ohio State University, Columbus, Ohio 43210.—This study examined the explicit assumption made in some archaeological vegetation reconstructions that vegetal resources will vary significantly between different physiographic zones in a given region. Using data from southeastern Indiana and southwestern Ohio, this assumption was worked into hypothesis form and tested. The methodology employed in testing was statistical and probabilistic in nature.

OTHER PAPERS READ

Excavations at Wilbur Wright State Memorial: Techniques of Historical Archaeology. JOHN M. HARTMAN, Indianapolis, Indiana 46200.

The Commissary Site: Completion of Excavations at an Early Late Woodland Cemetery. H. CREE NEWBOLD, CHARLES A. ANDERSON and B. K. SWARTZ, JR., Department of Anthropology, Ball State University, Muncie, Indiana 47306.

A Report of an Archaeological Site Survey of Spiceland Township in Henry County, Indiana. H. CREE NEWBOLD and B. K. SWARTZ, JR., Department of Anthropology, Ball State University, Muncie, Indiana 47306.

Site Stratification in a Lacustrine Environment: Evidence from Highland Ecuador

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Abstract

During the summer of 1973 the Indiana University Museum initiated a program of research to identify the native adjustments to the environment of San Pablo Lake through time. It was possible to distinguish several topographic conditions which might be appropriate to differential prehistoric utilization.

Preliminary results indicate that the largest sites tend to be located either on the low hills which surround the lake or on the high ground near Peguche Falls. Another large site was located on the 7 meter terrace, but the terrace does not seem to have been heavily utilized for habitation sites. No large sites were found on the low ground between the terrace and the lake.

All of the sites are characterized by a red slip ware which apparently belongs to a ceramic tradition which continued into the Historic Period. Very little evidence of other ceramic traditions was found.

Introduction

The earliest evidence of settled life in South America comes from coastal shell mounds in areas where mollusk beds provided a stable resource base. Riverine stations with abundant fish resources probably were equally capable of sustaining settled life at an early date. Although no riverine stations have yet been dated prior to 3000 B.C., it seems significant that the earliest well defined pottery phase on the Ecuadorian Coast, the Valdivia Phase, is often found in riverine situations (9).

The research of Padre Porras in the Ecuadorian Oriente demonstrates the close relationship of early Pastaza ceramics with those of the Valdivia Phase. The Yasuni Phase of the Napo River seems to be a somewhat later member of this ceramic tradition (2, 8). If the Early Formative ceramic complexes from both sides of the Ecuadorian Andes are closely related, contemporary cultures in the Andes might have served as intermediaries between the early ceramic complexes to the east and west.

Although the best known Valdivia sites are coastal shell middens (8), there are also sites on the Daule River in which the nature and quantity of the refuse indicate that settled communities, or villages, must have existed as early as Valdivia A (9). Fish from the river would have been a major food resource and we know also that maize was cultivated by peoples of the Valdivia Phase (13). In short, at least some of the Early Formative Period sites of coastal Ecuador could have based their subsistence on fishing and agriculture, supplemented by wild food resources, precisely the same subsistence base that is most likely for contemporary cultures on the upper Napo and Pastaza Rivers in eastern Ecuador. Related cultures in the Ecuadorian Andes

are most likely to be found in areas which most closely approximate the critical resource potentials of coastal and eastern rivers.

Even though the rivers of the coast and of the Oriente penetrate the Andes, they are not the most likely place to look for early Formative settlements because their character is markedly different in the two zones. Instead of meandering rivers with broad floodplains which characterize the coast and Oriente, in the Andes we find deeply dissected, rapidly flowing rivers with very restricted flood plains. While fish undoubtedly were found in these Andean rivers, it seems unlikely that they existed in sufficient numbers to support settled populations comparable to those on the coastal rivers or in the Oriente. Fish populations large enough to support large settled communities probably existed only in the highland lakes.

There are four highland lakes in the Andes north of Quito: Mojanda; Cuicocha; Yaguarcocha and San Pablo. Lake Mojanda, at 3716 m, and Lake Cuicocha, at 3068 m, are probably too high to support very much early agriculture. Therefore, our efforts focused on San Pablo Lake (2661 m) (Fig. 1) which is well known for its modern Indian populations (1) as well as for its importance in the late prehistoric (4, 12) and early historic periods (11). Among other things, we hoped to establish the relationship between modern and prehistoric populations as an aid to archaeological interpretation. Other parts of the total study will include ethnographical and botanical research.



FIGURE 1. Archaeological sites near San Pablo Lake, Ecuador. Source of base map: Servicio Geografico Militar, Mapas Topograficos: Illuman, Otavalo and San Pablo sections. 1938.

The Andes of northern Ecuador is a volcanic region, much of it of fairly recent origin. The upper geological strata are characterized by soft, easily eroded ash layers. Major rivers such as the Guayallabamba and Ambi are deeply incised with little or no floodplain. However, some of the upper tributaries of these streams have U-shaped valleys with broad, relatively flat bottoms in which the rivers have cut no more than a few meters below the floor of the valley.

The Provinces of Imbabura and Pichincha are well known for their large earthen mounds, called *tolas*, which have been reported by various authors. Although many of these mounds have been excavated (5, 6), the nature of the reporting makes it difficult to know precisely what is involved. Evidently, there are at least three basic forms of tola: a circular tola, often with a central burial; a rectangular tola; and a rectangular tola with a long ramp. Recent work conducted at tola sites (10) should make it possible to re-evaluate the earlier data. Our project, however, was not directed toward the study of these ancient monuments but rather toward a systems analysis of the San Pablo Lake area. We feel this area is likely to produce a long archaeological sequence during which the relationships between the lakeside niche and other niches changed in response to changing environmental and sociological conditions. The first season's work was devoted primarily to archaeological survey, with some testing, and to archaeological salvage projects in conjunction with the Instituto Otavaleño de Antropología.

Geographical Description

Nestled among the hills of the Province of Imbabura, Lake San Pablo covers an area of a little more than 6 km². The lake is teeming with bass, trout and carp which have been introduced in the last few decades. At the time of the Spanish Conquest, the only fish species in the lake was the preñadilla (*Pimelodes cyclopus*), a small fish less than 10 cm in length which was trapped on dark nights (11). The modern Indian populations seem to make little use of the lake for either fishing or collecting edible plants. However, they continue to make reed boats which are similar in construction to those found on Lake Titicaca and the north coast of Peru. The modern Indians grow such crops as maize, quinoa, beans and peas around the lake and on the low hills: a little higher up potatoes are grown. The fields closest to the lake are utilized as pasture.

Within the vicinity of the lake we recognize seven ecological zones which seem to offer somewhat different advantages for site location. Zone A refers to the hills which separate Otavalo from San Pablo Lake. The tops of these hills are suitable for dry farming but since there are no springs for domestic use, water would have to be carried from below. The hills were thoroughly surveyed except in the extreme northern sector. Ten sites were identified including several large sites (OT-5, 6, 11), tola (OT-9), and a site with a circular configuration (OT-12), locally known as Arbol Pucara.

Zone B includes the area from the base of the hill to the edge of the terrace (Fig. 2). It also includes areas above the edge of the

terrace elsewhere around the lake. Sites in Zone B would have ready access to lacustrine resources and also to level areas suitable for dry farming. However, the streams are too deeply incised to permit irrigation. This zone was surveyed at the western end of the lake and 14 sites were located, only one of which (OT-20) approaches the size of the large sites in Zone A.

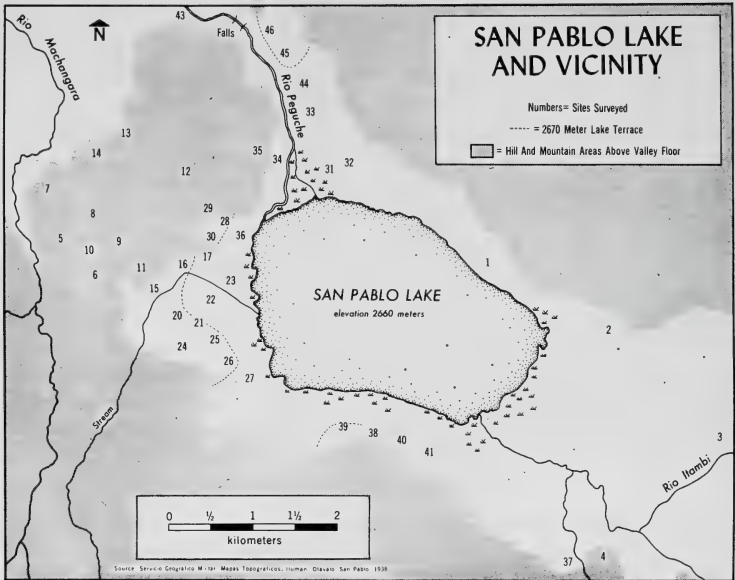


FIGURE 2. *Provinces of Imbabura and Pichincha. Source: Instituto Geográfico Militar, Map of Ecuador. 1971.*

Zone C refers to the lands below the terrace which slope gradually toward the lake. Much of this land is sufficiently low-lying that it is subject to occasional flooding. Five small sites were found in this area.

Zone D refers to the foothills which approach the lake. They are somewhat lower and have better access to water than Zone A, but otherwise seem very similar. All three of the areas classified as Zone D have modern villages. Four sites were found in San Rafael at the southern end of the lake (OT-38, 39, 40, 41); one very large site in Gonzalez Suárez at the southeastern corner (OT-4); and one site in Araque (OT-2) which may be nearly as large as the one in Gonzalez Suárez.

Zone E is the floodplain of the lower Rio Itambi, which is irrigable. There is a group of circular tolas (OT-37) about 2 km from the lake.

Zone F is the Peguche Valley above the falls. The river has a small floodplain which might be irrigable but most of the land is

suitable only for dry farming. Six sites were found in Zone F including three large sites just above the falls (OT-44, 45, and 46). Several irrigation canals begin at the falls. The low, wet area below the falls is characterized by many stinging insects. No one lives there today and it was probably also an unattractive place in the past.

Zone G refers to the valley which extends northeastward from the lake, drained by the upper Rio Itambi, which is deeply incised into the broad floor of the valley. Although little work was done in Zone G, one site (OT-19) was found on the floor of the valley, and another (OT-18) at the edge of the valley, close to a spring.

Artifacts

Red slipped ware is prominent at all sites. It is associated with a plain ware, often with red slipped rims. The red ware vessel forms most frequently encountered include footed bowls and small ollas. Large jugs with an unpolished red slip are also common on some sites. Plain ware vessels are typically jars or ollas which sometimes have tall, solid tripod supports. Strap handles and tall, narrow flat bases are sometimes found as well. Decoration other than a red slip is very rare. Rectilinear red-on-natural painted decoration is found at several sites. The fragments are too small to permit design reconstruction but both cross-hatch and "V" design fragments can be observed. Pellet applique decoration, typically associated with a rim form suggestive of a cambered jar (8) is also found at several sites.

The aggregate of sherds collected from OT-11 stands out from all of the other sites in the area that have been collected so far, in that the range of design motifs and decorative techniques is far greater than has yet been identified at any other site. In addition to the combed decoration and pellet applique decoration, the aggregate of sherds from OT-11 exhibits at least four other modes. These include a pair of circumferential grooved lines above the shoulder angles; several sherds with diagonal incised decoration; an engraved band design above the shoulder angle; and a reed punctate and dot motif. In spite of the difference in sample size, there can be little doubt that OT-11 is a multi-component site, one of the very few that we have been able to identify so far.

Obsidian artifacts were also found in varying frequencies at all sites. Despite excellent raw material, examination of thousands of obsidian chips and fragments has not revealed the presence of a single piece which appears to have been worked into a predetermined form or that shows evidence of bifacial flaking. While the edges of some of the flakes appear to have been modified to form a working edge, the obsidian industry as a whole can be characterized as a utilized flake industry. At this point, we are not prepared to say anything about edge utilization differences from one site to another.

Ground stone tools were also found on many sites. For the most part, these were manos of which there appear to be two major

varieties: the first has a circular cross-section; the second has a triangular or trapezoidal cross-section. In museum collections and around modern house sites we have seen trough metates which might be expected to be associated with the second type of mano. When questioned, the Indians using these metates say that they are old, but from our own evidence we cannot associate this metate form with any particular site.

Discussion

The archaeology of the highlands of northern Ecuador is very poorly known. Although there are a few radiocarbon dates, the materials with which they are associated have not been published. Neither is there a verified stratigraphic sequence anywhere in the area. While there is a seriation of grave associations from the Province of Carchi (3), it deals mostly with more elaborate materials than have been found in our surface collections. Comparisons also can be made with materials from the Oriente and from the Coast.

The chronological system employed here was developed by Meggers (7), based largely upon dated materials from coastal Ecuador. The ways in which this system can be extended to the highlands is open to considerable doubt which can only be removed when the development of highland cultures becomes better known.

Formative Period (2500 B.C. to 500 B.C.)

OT-11 appears to have been occupied during the early Formative Period since it shares a number of traits with the Valdivia and Machalilla Phases of the Coast (8). These include closed mouth carinated bowls, double spout and bridge vessels and jars with cambered rims as well as red-on-natural painted designs, bands of diagonal incisions, grooved decoration, pellet applique, and pottery discs. Side by side comparison of these sherds from OT-11 with those from a coastal site of the Valdivia Phase indicates that our sherds could easily be lost among the Early Formative materials from the Coast. The high degree of similarity is surprising because of the distance between the two sites. However, other characteristics of Valdivia and Machalilla Phase pottery, such as zoned cross-hatch decoration, do not appear in our collections. Nevertheless, there can be little doubt that the occupation of OT-11 dates back to the early Formative Period, probably prior to 2000 B.C. At OT-5, 20 and 45 pellet applique decoration on a cambered rim, virtually identical to the examples from OT-11, suggests that these sites may also have been occupied during the Formative Period. Other artifacts suggestive of Formative occupation were also found at OT-1 and 44.

Sites of the Formative Period are found in four of the ecological zones: Zones A, B, C and F. The site in Zone C is located on a low rise well above present lake level. The quantity and extent of the refuse indicate that it is a very small site, probably occupied for a very short period of time. The area covered by Formative refuse at OT-11 is much larger, but not so great as the later occupations of the site.

Regional Developmental Period (500 B.C. to 500 A.D.)

Resist painted pottery associated with deep shaft and chamber graves is characteristic of this time period from the middle Cauca Valley, in Colombia, to the north coast of Peru. This combination has been identified at two sites in the vicinity of San Pablo Lake: OT-4 and OT-18. However, the apparent absence of resist painted wares cannot be taken to mean that other sites were not occupied during this period. Resist decoration is highly fugitive so the smallest amount of surface abrasion or weathering would eliminate all traces of it. Typically such decoration is found on a red slip in the Carchi area (3). As noted, red slip is found on all sites around San Pablo Lake.

Sites definitely belonging to the Regional Developmental Period are found in Ecological Zones D and C. However, sites of this period may yet be identified in other ecological zones.

Integration Period (500 A.D. to 1500 A.D.)

There is a large number of sites which share several ceramic traits characteristic of the Integration Period. These include footed bowls and ollas, vessels with solid conical tripod supports and vessels with heavy triangular rims. Even though we have small surface collections from many sites, 18 of them share two or more of these characteristics.

Sites of the Integration Period occur in Ecological Zones A, B, C, D, and F. In addition, the group of circular tolas in Zone F probably belongs to the Integration Period. The largest sites are located in the southern part of Zone A (OT-5, 6 and 11) and in the northern part of Zone F (OT-44, 45 and 46). The sites in Zone F would have been in an ideal location to control the flow of water into irrigation canals which begin at the falls. Since we found evidence of irrigation during the Integration Period near Cayambe, it is possible that the control of irrigation waters was an important consideration in the placement of sites above the falls.

Not only are there more sites which belong to the Integration Period, but the sites are also larger than those of earlier periods. Since there is no evidence to suggest massive immigration from other areas, we attribute the apparent increase in population to the normal processes of population growth.

In the final phase of the Integration Period, northern Ecuador fell under the control of the Inca Empire. The seat of Inca power at San Pablo Lake was probably at Arbol Pucará (OT-12). To date, we have found no archaeological evidence that *mitimae* populations were introduced by the Inca to consolidate their control.

Historic Period (beginning 1500 A.D.)

Documentary references (11) to towns of the Early Historic Period mention many centers which continue to be occupied. In addition to these centers we have identified one site (OT-15) which was occupied during the early Historic Period. A feature salvaged from this site produced red slip footed bowls and footed ollas very similar to those of

the Integration Period. However, the specimens from OT-15 were made on a fast wheel—a technique of pottery manufacture which was not known in the New World prior to the arrival of the Spanish. Thus there is evidence of cultural continuity between the prehistoric period and the modern Indians of Otavalo.

Conclusions

Archaeological evidence from San Pablo Lake suggests that the area was occupied during the Formative Period, probably before 2000 B.C. Although the area continued to participate in developments that were taking place elsewhere in Ecuador, there is nothing to suggest massive immigration or foreign control before the Inca invasion in the late Integration Period. While the inhabitants of San Pablo Lake must have been in contact with the outside world, they appear to have retained control of their own destiny, accepting or rejecting foreign ideas as they saw fit. This situation contrasts with the culture history of the Central Andes which is characterized by the rise and fall of empires. The societies of the highlands of northern Ecuador appear to have followed their own road to the development of complex society, unaffected by the spread of Peruvian empires until they were finally conquered by the Inca.

Acknowledgements

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A Report on the Disposition of Ten Discontinuous Cranial Traits in the Indian Knoll Skeletal Population

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Abstract

One hundred and seven crania (47 male, 46 female and 14 juveniles of undetermined sex), were sampled for 10 non-metric skeletal variants. Associations between trait incidence and age, and trait incidence and sex, were tested for, using contingency tables and the Chi-square test, with a confidence level of $\alpha=0.05$. Previous investigators have claimed that these skeletal variants are free from age and sex effects. No significant association between trait incidence and sex was discovered; however, one trait showed a strong association with age.

Discontinuous skeletal traits appear in most individuals and are characterized as extra foramina, sutural bones, processes, irregular sutures, tori, exostoses and fossae. These traits have recently been recognized by anthropologists as valuable means for determining the biological affinities of prehistoric human populations (2, 6). Employment of these traits can assist physical anthropologists and archaeologists in the reconstruction of population relationships, which in turn, can be applied toward establishing the probable geographic movements of prehistoric man. Furthermore, these traits are valuable for micro-evolutionary studies (5).

Discontinuous skeletal traits were shown to be genetically transmitted and stable under variable environmental conditions (2). In addition, Berry and Berry (2) claim that these traits are non-age and non-sex specific as well as being "discontinuous", *i.e.* not present in all individuals. Because of their discrete nature and their unique qualities, the investigator can assess and score them rapidly, plus pool all age groups and the sexes in the sample, thereby more reliably reflecting the gene pool.

However, Buikstra (3) demonstrated that some of these traits are in fact age specific and sex specific in some populations. Other researchers (1, 4, 7) have submitted findings that suggest some of these traits are inter-related as well as being significantly affected by abnormal environmental conditions, such as cradle boarding.

This study was conducted to: 1) record the incidence of ten discontinuous cranial traits in a prehistoric skeletal population, and 2) to test the hypothesis that discontinuous traits are not age or sex related.

Materials and Methods

Crania of 47 male, 46 female and 14 juveniles were selected from over 1,000 skeletons housed at the University of Kentucky, Lexington. They were excavated from the Indian Knoll site on the Green River in the southern edge of Ohio County, Kentucky. Occupation of the site

was probably between 2500 and 2000 B.C. (Archaic Period, as defined by New World prehistorians). The economy of the Indian Knoll people was based on a hunting and gathering technology (8). Only intact or partially damaged crania were studied. No deformed or pathological specimens were used. Sutural bones in partially obliterated sutures were not scored (3, 7).

Ten traits were recorded (Table 1). These were selected from facial, frontal, lateral, occipital and basilar areas of the skull. They include foramina, sutural bones, fossae and irregular sutures. This selection of traits provides a sampling of the total cranial area. Descriptions and illustrations of these traits were provided by Berry and Berry (2). Unilateral traits were scored for presence/absence. Bilateral traits were scored for presence on the right, left, both sides or absence on both sides.

Tests for trait incidence-age associations were made between two age groups: sub-adults, (0-15 years) and adults (16 years and older). Tests for trait incidence-sex associations were made between males and females of all ages. Associations were tested for significance by Chi-square.

Results

Only one significant association was noted when testing for trait incidence-age associations. The tympanic dihiscence showed a strong age effect (Table 1). No statistically significant associations between trait-incidence and sex were discovered.

For the sub-adult group, there was a total absence of coronal ossicles and fronto-temporal articulation. The absence of these traits in sub-adults as well as the rarity of parietal foramen and epipteric bones for the total sample points to the population's homogeneity.

TABLE 1. *Tests for age and sex associations using Chi-Square Test.*

Trait	Age			Sex		
	Chi-square	Observed	d.f.	Chi-square	Observed	d.f.
	0.05	Value		0.05	Value	
Parietal Foramen	7.81	5.22	3	7.81	2.50	3
Coronal Ossicle	7.81	.60	3	7.81	.003	3
Epipteric Bones	7.81	1.45	3	7.81	4.76	3
Fronto-Temporal Articulation	7.81	.34	3	7.81	1.06	3
Mastoid Foramen Exsutural	7.81	5.91	3	7.81	.56	3
Anterior Condylar Canal Double	7.81	2.41	3	7.81	4.16	3
Foramen Spinosum Open	7.81	3.04	3	7.81	2.18	3
Pharangeal Fossa ¹	3.84	1.55	1	3.84	1.65	1
Infra-Orbital Suture	7.81	4.30	3	7.81	1.27	3
Tympanic Dihiscence	7.81	22.44*	3	7.81	6.46	3

¹ Unilateral trait. *Significant at the 0.05 level.

Conclusions

To use discontinuous skeletal traits for establishing biological affinities, measuring genetic distance, or demonstrating movements of pre-

historic man, one must first show that these variants are without sex or age associations. In this way, one can reliably pool a large portion of a skeletal population including both the young and old as well as the sexes (2, 3, 7), and as a consequence, more accurately reflect the population's gene pool.

However, as Buikstra (3) pointed out, pooling sexes and age-groups is not possible for all traits. Indeed, this study supports both Buikstra's and Jantz's findings that there are age and sex specific traits. Buikstra (3) suggested that proper coping techniques be used for such problem traits.

Tympanic dehiscence (a foramen in the floor of the auditory canal) was shown to be age specific in other populations (3, 7) and was proven to be age specific in the Indian Knoll population. It is not known at what age the tympanic dehiscence stops being "a normal developmental event . . . and becomes a developmental anomaly" . . . (3). This trait may also "age" at different rates in different populations (3).

In short, our knowledge of the etiology and ontogeny of traits like tympanic dehiscence is limited. Some early workers have claimed that discontinuous skeletal traits are free of age and sex associations; however, it is strongly suggested from this study, that age and sex first be routinely inspected, before pooling sexes and age groups for comparative studies.

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BOTANY

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ABSTRACTS

Early Development of Anthers in the Maize Mutant, Tassel Seed-2. CHARLES FELLING and CHARLES L. GEHRING, Department of Life Sciences, Indiana State University, Terre Haute, Indiana, 47809.—Anther development of the maize mutant tassel seed-2 (heterozygous state) was studied by light and electron microscopy. Anther development from locule formation to premeiotic prophase was divided into five reasonably distinct developmental ranges and locule lengths were determined. Stage one locules (50-150 microns) consist of central meristematic (archesporial) cells and an epidermal layer. In stages two (150-300 μ) and three (300-600 μ), the hypodermal cells give rise to the primary parietal and primary sporogenous cells; the former then give rise to the endothecium and parietal layers. Anther wall formation is completed during stage four (600-1300 μ) as the parietal layer gives rise to middle and tapetal layers. Callose deposition begins around the sporogenous cells as they enter meiosis at stage five (1300-2300 μ). The large sporogenous cell nucleoli contain prominent 'nucleolar vacuoles' throughout development. Two nucleoli per nucleus are frequently seen at stage two, occasionally at stage three, but have not been observed at the later stages. Starch (which is never present in the sporogenous cells or the adjacent cell layer during development) progressively increases both in number and size of grains in the outer cell layers and becomes particularly prominent in the endothecium. At early stages all locule cell walls are uniformly thin. By stage three the periclinal walls of the endothecium have greatly thickened. The other cell walls remain thin, though they differ in structure (middle and tapetal walls are extraordinarily thin and the anticlinal epidermal and endothelial walls are 'wavy'). Plasmodesmata traverse all cell walls throughout development. Organelles typical of meristematic plant cells were present in all tissues.

Ultrastructure of Plastid Entities in Cells of Genetic Albino Leaf Callus of Phenotypically Green Origin. ANNE A. SUSALLA, Department of Biology, Saint Mary's College, Notre Dame, Indiana 46556.—Young tobacco callus cells from genetic albino leaf tissue of phenotypically green origin have plastid entities unlike those found in mature leaf cells of similar origin. Plastid entities in callus cells are variable in shape and may contain invaginations enclosing cytoplasm and organelles. A prolamellar body is occasionally observed but thylakoids have not been identified. The plastid membrane is observed to be diffuse in some

areas, even though membranes of nearby organelles are intact. Tubular and vesicular structures that appear to be part of a peripheral reticular system are present in marginal areas of the stroma. Starch grains are commonly present.

A Robust Form of *Echinochloa muricata*. D. JAMES MORRÉ, Department of Botany and Plant Pathology, Purdue University, West Lafayette, Indiana 47907.—A robust form of barnyard grass, *Echinochloa muricata* (Beauv.), was collected in early September 1973, on the west bank of the Wabash River between Mascouten Park and the river (Indiana Highway 43 North) in Tippecanoe County, Indiana. The plants were in the late stages of anthesis and growing in association with typical forms of *E. muricata* and *E. crus-galli* (L) Beauv. Six specimens were obtained from a single colony of about 12 plants. The culms were erect or decumbent at the base, stout, succulent, up to 1 centimeter in diameter, branched, and over 2 meters tall. The leaf sheaths were glabrous; blades elongate, 20-25 millimeters wide, and scabrous above. The panicles were erect or nodding, deep purple to purple-tinged, and 15 to over 40 centimeters long. Racemes were spreading, ascending, or appressed, the lower as much as 12 centimeters long, mostly branched with 10-20 primary branches. The spikelets were crowded, 3.5 millimeters long excluding the short awns. Internerves were glabrous and the nerves were strongly tuberculate. The fertile lemmas lacked the ring of minute hairs below the tip to distinguish the spikelets from those of *E. crus-galli*. The second glume and sterile lemma had mostly pustular bristles, a characteristic of *E. muricata*. Awns were variable, mostly 1.5 to 2.5 millimeters long, up to 5 millimeters long, up to 5 millimeters long on some of the spikelets. Except for their unusually large size, the specimens could not be distinguished from a short-awned form of *E. muricata*.

Robust forms of Green Foxtail (*Setaria viridis* var. *robusta-purpurea* Schreiber and *S. viridis* var. *robusta-alba* Schreiber) have recently invaded Indiana and present a serious new weed menace. A robust form of *E. muricata* could be equally serious if established in Indiana's bottomland fields.

Spore Viability in a Fifty-one-Year-Old Sporocarp of *Marsilea quadrifolia*. WILLIAM W. BLOOM, Biology Department, Valparaiso University, Valparaiso, Indiana 46383.—A sporocarp of *Marsilea quadrifolia* collected in 1922 was germinated in the summer of 1973. Seventy-two of 73 megaspores produced female gametophytes and many of the microspores produced functional male gametophytes. Seventy-one of the female gametophytes gave rise to sporophytes.

Meiotic Chromosome Behavior in *Rhoeo spathacea* (Swartz) Stearn

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Abstract

Each of the 12 chromosomes of the tropical monocot, *Rhoeo spathacea*, is involved in a translocation with two other chromosomes. This unusual chromosome constitution results in unique synaptic arrangements of the chromosomes in prophase I and metaphase I of meiosis and atypical chromosome segregation at anaphase I. Using the acetocarmine squash technique, 5436 pollen mother cells from 16 *Rhoeo* plants were examined, including 281 at diakinesis/metaphase I, 1,310 at anaphase I, and 3,845 at telophase I. Data on the frequencies of rings of 12 chromosomes and various chromosome chain configurations at diakinesis were determined. Similarly, the frequencies of 6:6, 5:7, 5:1:6, and 5:2:5 anaphase I chromosome segregation patterns were recorded. Telophase I cells were studied to determine the frequency of those containing micronuclei and excluded chromosomes.

Meiotic chromosome behavior in pollen mother cells (PMCs) of *Rhoeo spathacea* (Swartz) Stearn [synon. *Rhoeo discolor* (L'Heritier) Hance] has fascinated cytologists since Belling (2) first reported that the chromosomes of this plant form a ring of 12 during meiosis I. This synaptic relationship is produced because no two chromosomes in *Rhoeo* are identical. Rather, every chromosome is involved in a translocation with two others. A number of investigators, beginning with Darlington (3), have reported on the consequences of these multiple translocations on meiotic chromosome behavior in *Rhoeo*. Among these consequences are ring and chain formation at diakinesis, alternate *vs.* adjacent chromosome alignment at metaphase I, and atypical segregation patterns, such as 5:7, 5:1:6, and 5:2:5 at anaphase I.

The Study

In the process of investigating the cytology of a greenhouse population of 16 *Rhoeo* plants of unknown origin, 5,436 PMCs were examined, including: 281 at diakinesis/metaphase I, 1,310 at anaphase I, and 3,845 at telophase I. Using the acetocarmine squash technique to examine PMCs, each of the 16 plants was shown to have $2n = 12$ and all plants were found to exhibit chromosome behavior consistent with the hypothesis of multiple translocations, as generally reported in the literature.

Cytological Data

Table 1 gives a concise account of the numbers and frequencies of the various chromosome configurations observed in the 5,436 PMCs, while Table 2 compares the data obtained for 281 PMCs at diakinesis/metaphase I with similar data reported earlier (3, 6, 7). Data for 489 PMCs from Lin's unpublished study (5) are not included.

Table 3 summarizes data concerning chromosome segregation patterns observed in 1,310 anaphase I cells in the present study and compares these data to those obtained in less extensive studies (1, 3, 4, 6, 7).

Table 3 indicates that in some cases chromosome distributions were determined during meiosis II rather than in metaphase I or anaphase I. Lin (5) reported additional data on chromosome segregation patterns in 240 PMCs at metaphase I or anaphase I.

TABLE 1. *Data obtained on meiotic behavior of chromosomes in 5436 PMCs of Rheo spathacea.*

Meiotic Stage	No. PMCs	%	Specific Types (and Frequencies) of Indicated Configurations
Diakinesis			
Ring of 12 -----	88	31.32	
Chain of 12 -----	99	35.23	
Two Chains -----	65	23.13	11+1 (15); 10+2 (21); 9+3 (11); 8+4 (9); 7+5 (7); 6+6 (2).
Three Chains -----	18	6.41	10+1+1 (1); 9+2+1 (1); 8+3+1 (1); 7+4+1 (1); 7+3+2 (3); 6+5+1 (3); 6+4+2 (1); 6+3+3 (1); 5+5+2 (3); 5+4+3 (3).
Four Chains -----	10	3.56	9+1+1+1 (1); 5+3+3+1 (4); 5+3+2+2 (2); 4+4+3+1 (2); 4+3+3+2 (1).
Five Chains -----	1	0.36	4+4+2+1+1
Total -----	281	100.01	
Anaphase I			
6:6 -----	779	59.47	
5:7 -----	280	21.37	
5:1:6 -----	200	15.27	
5:2:5 -----	32	2.44	
Others -----	19	1.45	4:1:7 (7); 4:3:5 (2); 4:2:6 (4); 9:3 (1); 4:8 (2); 4:6:2 (1); 4:2:1:5 (1); anaphase bridge (1).
Total -----	1310	100.00	
Telophase I			
Normal -----	3606	93.8	
Abnormal -----	239	6.2	
Total -----	3845	100.0	

Among the 3,845 telophase I cells studied, 239 or 6.2% were classified as abnormal because they contained excluded chromosome or micronuclei. Since 40.53% of the 1,310 anaphase I cells were found to exhibit abnormal segregation (*i.e.*, 5:7, 5:1:6, 5:2:5, etc.), an explanation of the relatively low frequency of abnormal telophase I cells would seem to be required. Three possible causes of this difference may be suggested: 1) Cytoplasmic enzymes may destroy chromosomes excluded at anaphase I so they do not appear in telophase I cells; 2) Chromosome lagging at anaphase I, and therefore producing 5:1:6 and 5:2:5 configurations, may finally be included in one of the daughter nuclei at telophase I; 3) An abnormal 5:7 distribution recognized at anaphase I with no difficulty will not be readily detected as abnormal at telophase I.

TABLE 2. *Frequency of ring and chain formation reported in several studies of meiosis in Rhoeo.*

Diakinesis Chromosome Configuration	Darlington (3)	Simmonds (6)		Walters and Gerstel (7)	Mertens
		Coll. 1	Coll. 2		
Ring of 12					
No.	—	6	5	32	88
Freq.	30%	15.0%	16.7%	32%	31.32%
Chain of 12					
No.	—	9	10	38	99
Freq.	45%	22.5%	33.3%	38%	35.23%
2 Chains					
No.	—	7	8	15	65
Freq.	20%	17.5%	26.7%	15%	23.13%
3 Chains					
No.	—	3	2	14	18
Freq.	5%	7.5%	6.7%	14%	6.41%
4 Chains					
No.	—	—	—	1	10
Freq.	—	—	—	1%	3.56%
5 Chains					
No.	—	—	—	—	1
Freq.	—	—	—	—	0.36%
Not Specified					
No.	—	15	5	—	—
Freq.	—	37.5%	16.7%	—	—
Total No. Cells	—	40	30	100	281

TABLE 3. *Summary of data reported in several studies of the frequency of various anaphase I chromosome distributions in Rhoeo.*

Chromosome Segregation Pattern	Darlington (3)	Kato (4)		Akemine (1)		Simmonds (6)		Walters and Gerstel (7)	Mertens
Stage	A II	A I	M II	M I	A I	A I	A I	M II	A I
6:6									
No.	37	59	86	72	107	8	37	35	779
Freq.	93%	62.8%	65.7%	72%	77.5%	66.7%	56.1%	70%	59.47%
5:7									
No.	3	30	45	23	20	1	11	15	280
Freq.	7%	31.9%	34.3%	23%	14.4%	8.3%	16.7%	30%	21.37%
5:1:6									
No.	—	3	—	5	9	2	12	—	200
Freq.	—	3.19%	—	5%	6.52%	16.7%	18.3%	—	15.27%
5:2:5									
No.	—	2	—	—	2	—	2	—	32
Freq.	—	2.1%	—	—	1.44%	—	3%	—	2.44%
Others									
No.	—	—	—	—	—	1 ¹	4 ²	—	19 ³
Freq.	—	—	—	—	—	8.3%	6%	—	1.45%
No. Cells	40	94	131	100	138	12	66	50	1310

¹(6:3:3); ²(6:2:4), (7:1:4), and (5:3:4), ³(8:4), (9:3), (7:1:4), (5:3:4), (6:2:4), and (4:2:1:5)

Commentary

The present study revealed a number of diakinesis and anaphase I configurations not previously reported in the literature or by Lin (5). These include the three-chain diakinesis configurations of 7+3+2, 6+3+3, and 5+4+3 and all of the four-chain and one, five-chain configuration listed in Table I. Two previously unreported anaphase I distributions, 9:3 and 4:2:1:5, were also noted in the present study. These data suggest that the discovery of various infrequent chromosome configurations only awaits the study of a sufficiently large population of PMCs. Finally, the telophase I data obtained in this study, showing approximately 6% PMCs having lagging chromosomes or micronuclei, are not inconsistent with results reported by Walters and Gerstel (7), who found 4 abnormal telophase I PMCs in a population of 100.

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CELL BIOLOGY

Chairman: CARL W. GODZESKI, Eli Lilly Research Wing,
Marion County General Hospital, Indianapolis, Indiana 46200

CARL W. GODZESKI, Eli Lilly Research Wing,
Marion County General Hospital, Indianapolis, Indiana 46200,
was elected Chairman for 1974

ABSTRACTS

Preparation of Microbes for Scanning Electron Microscopy (SEM). LEE F. ELLIS and LINDA K. SAMPSON, Eli Lilly and Company, Indianapolis, Indiana 46206.—Microbiologists grow bacteria and fungi in either broths or on agar surfaces, and each case presents problems for the electron microscopist. When broth cultures are used, components in the media form crystals or an amorphous coating on the cells. Generally cells were fixed and washed in buffer, but for higher resolution alcohol rinsing was tried. *Streptomyces cinnamonensis* fermentation cultures were used in this study.

Colonies of *Cladosporium* sp. and *Streptomyces cinnamonensis* were grown on Sabouraud's plates and were fixed with osmium vapor. Small pieces were removed and prepared for scanning electron microscopy with the following procedures:

- 1) Air dried
- 2) Graded alcohol dehydration and air dried
- 3) Graded alcohol dehydration and critical point dried
- 4) Graded alcohol dehydration, held overnight in 100 per cent alcohol and critical point dried

All the specimens were coated with gold and examined in the SEM. The best dehydration was attained when the agar pieces were held overnight in alcohol. Both the vegetative organisms and spores show wrinkles in their surfaces when dehydration was incomplete.

Scanning Microscopic Comparison of Starch Grains from the Latex of *Euphorbia* Species. PAUL G. MAHLBERG, Department of Plant Sciences, Indiana University, Bloomington, Indiana 47401.—A morphologic comparison of starch grains from latex of different species of *Euphorbia* shows that grain morphology differs between each species. In addition, the morphology of these grains in any one species differs from grains present in other cells within the plant body. Four classes of grains were identified in different latices: elongated, osteoid, osteoid-lobed, and discoid. The average length and maximal length of grains also can differ in species possessing a similar class of grain. The elongated grain was present in three non-succulent species examined, *E. heterophylla* L., *E. pulcherrima* Willd. and *E. terracina* L., where the maximal length of recorded grains was 158, 70 and 27 microns, respectively. Latex in succulent species most frequently contained grains with an

osteoid or variation of the osteoid morphology. In some species, the enlargement of the grain ends was minimal as in *E. valida* Br. (maximum length, 48μ) and in *E. viguieri*, Denis (maximum length, 33μ) while in *E. abyssinica* Gmel. (maximum length, 35μ), *E. tirucalli* L. (maximum length, 49μ) and *E. trigona* Haw. (maximum length, 62μ) the grain ends are progressively more flared. The development of additional lobes along the mid-region of the grain characterized *E. inconstantia* Dyer (maximum length, 55μ) and the osteoid ends were frequently lobed. The grains in *E. lactea* Haw. showed a complex development in that multiple lobes developed along the mid-region as well as the ends to form a discoid grain (maximum length, 36μ). The variations in starch grain form suggests that their morphology is genetically controlled. This feature will make it possible to interpret the genetical basis for grain morphology and provide a criterion for interpreting the evolution of the laticifer within the genus *Euphorbia* and the family Euphorbiaceae.

VLB Effects on CHO Cells As Seen By Scanning Electron and Phase Microscopy. LINDA K. SAMPSON, GEORGE BORDER, and LEE F. ELLIS, Eli Lilly and Company, Indianapolis, Indiana 46206.—Control and VLB (vinblastine)-treated cell cultures of a Chinese hamster ovary line were examined by phase microscope time lapse photography and scanning beam electron microscopy for additional data on the mechanism by which VLB alters cellular division.

Many investigators document the growth inhibiting activity of vinca alkaloids to be due to metaphase arrest. We found correlation with that effect on the mitotic cycle of this particular cell line by use of phase time lapse photography and scanning electron microscopy.

For the scanning electron microscopy studies, non-synchronized control cells and cells subjected to 10^{-4} micrograms per milliliter of VLB for 5.0 hours were established as 24-hour cultures on glass coverslips. The cells were subsequently glutaraldehyde-fixed, ethanol dehydrated, critical point dried, and vacuum gold coated.

Time-potential metaphase accumulation is easily demonstrated during time lapse microscopy. This compares favorably with the surface morphology shown by scanning electron microscopy, which also demonstrates pronounced increase in metaphase-arrested cells of the VLB-treated cultures over the controls. Morphologically, the rounded-up, spherical cells in metaphase can be easily distinguished from the stretched or retracting surfaces containing numerous blebs and microvilli which are characteristic of G_0 , G_1 , S, and G_2 phases.

At present, this information suggests a possibly reliable system for use as a further aid in studying the *endogenous* mechanisms controlling the mitotic cycle.

A Cytological Study of the Uptake of Liposomes by HeLa Cells. J. D. SCHOKNECHT, W. E. MAGEE, and C. W. GOFF, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—Phospholipid spherules, or liposomes, were prepared from mixtures of sphin-

gomyelin, cholesterol and stearylamine. The enzyme horseradish peroxidase was trapped inside the particles in the aqueous phase during their preparation, thus providing a cytochemical marker for the particles. The particles were allowed to adsorb to cells as described previously (Magee, W. E. and O. V. Miller, *Nature* 235:339 (1972)), and the fate of the particles was followed over the succeeding 24 hours. The enzyme was localized by the Karnovsky staining procedure following glutaraldehyde fixation. The cells were postfixed in OsO_4 , embedded in an epon-araldite mixture, and examined by electron microscopy. Although no peroxidase staining could be detected in control cells, peroxidase positive material was observed in what appeared to be phagocytic vacuoles within 30 minutes after initial exposure to liposomes. Large aggregates of peroxidase-positive material apparently corresponding to liposomes were also present at the cell surface and in association with pseudopodia extending from the cell surface at 30 minutes and at all subsequent times. The cell membrane itself was stained over much of its free surface. The possible contribution of phagocytosis and of liposome fusion with the cell membrane in the acquisition of peroxidase staining at various loci will be considered.

Properties and Subcellular Distribution of Peroxidases of Onion Stem¹

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Abstract

Peroxidases detected by cytochemical procedures are compartmentalized in several cell components of meristematic stem cells of onion including cell walls and vacuoles. In fractions, however, most of the activity is soluble suggesting that the peroxidases are released as organelles are disrupted. As the duration of homogenization is increased, activities of glucose-6-phosphate dehydrogenase, acid phosphatase, and peroxidases at pH 6.5 and 7.0 increase in the soluble fraction. The membrane-bound enzyme succinic dehydrogenase is not solubilized by homogenization. We conclude that the peroxidases may be compartmentalized within the cell, but are readily solubilized by conventional cell fractionation techniques.

Peroxidases comprise a complex of enzymes found in most plant and animal cells. They catalyze the oxidation of a wide range of donors in the presence of hydrogen peroxide (16, 21, 30). Peroxidases have been implicated in cell division (28), fatty acid oxidation (27), lignification (3, 13), and in the synthesis and breakdown of the plant hormone indoleacetic acid (6, 25). Additionally, peroxidases are a class of enzymes that can be located at the subcellular level by electron microscopy (8, 10, 22, 24). Thus, they are especially useful as 'marker' enzymes for cytological studies. The purpose of this study was to determine the subcellular distribution of peroxidase activities using a combined cytochemical and biochemical approach.

Materials and Methods

Green onions (*Allium cepa* L.) were obtained commercially. The stem axes were cut from the onions using a scalpel with a narrow blade as described previously (18).

For cytochemical studies, stem axes were diced with a razor blade in 2% glutaraldehyde prepared in 0.1 M sodium phosphate buffer, pH 7.6. Tissue pieces approximately 1 mm in diameter were transferred to fresh buffered 2% glutaraldehyde and fixed for about 30 min. To localize peroxidases, the fixed tissue was washed with 0.1 M sodium phosphate buffer, pH 7.6 (3 changes of 20 min each) and incubated with a solution containing reduced 3, 3'-diaminobenzidine (2 mg/ml) and 0.02% hydrogen peroxide in 0.05 M tris-HCL buffer, pH 7.6 for 1 hour at 26° C as modified from Graham and Karnofsky (8). The tissue was then washed with 0.1 M sodium phosphate buffer, pH 7.6 (3 changes of 20 min each) and post-fixed with 2% osmium tetroxide buffered with 0.1 M sodium phosphate, pH 7.6. The tissue was washed

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with buffer, dehydrated through an acetone series, embedded in Epon and prepared for electron microscopy as described previously (26). Thin sections were examined and photographed with a Phillips EM 200 electron microscope.

To prepare cell fractions, 20 g of the tissue were finely minced with a razor blade (on a glass surface over ice) in 10 ml of homogenization medium. The homogenization medium consisted of freshly prepared 0.1 M K_2HPO_4 and 20 mM EDTA in Millipore-filtered coconut milk, pH 7.4, and containing 0.5 M sucrose (9). An additional 10 ml of homogenization medium were added, and the homogenization was continued for 3 min with a mechanical homogenizer, the Polytron (19), operated at 5,000 rpm. The homogenate was filtered through Miracloth, a porous inert fabric, to remove unbroken cells and debris. The filtered homogenate was then centrifuged at $8,000 \times g$ (7,000 rpm, Sorvall HB-4 rotor) for 15 min to remove nuclei, plastids, and mitochondria. The supernatant from this centrifugation was layered on a discontinuous sucrose gradient (29, Fig. 1) and centrifuged at $90,000 \times g$ (26,000 rpm, Spinco SW-27 rotor) for 60 min. The materials collecting at the gradient interfaces were collected with a Pasteur pipette, re-suspended in homogenization medium, and pelleted by centrifugation at $90,000 \times g$ for 45 min.

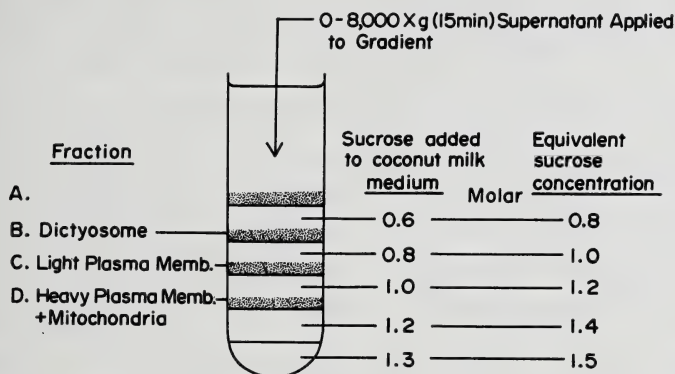


FIGURE 1. Diagram of the discontinuous sucrose and coconut milk gradient used to isolate membrane fragments (29).

In experiments to vary homogenization times, samples were removed at 30 sec intervals during Polytron homogenization. The samples were filtered through Miracloth and centrifuged for 30 min at $90,000 \times g$ (26,000 rpm, Spinco SW-27 rotor) to remove cellular membranes. The supernatant was used in the assays for soluble enzymes of Fig. 9.

All steps of cell fractionation and centrifugation were at $0-4^{\circ} C$. Centrifugal forces are approximate and calculated to the middle of the tube.

To monitor peroxidase activity of isolated cell fractions, guaiacol in the presence of hydrogen peroxide was oxidized to form tetraguaiacol

(Fig. 2). The formation of tetraguaiacol was followed spectrophotometrically at 470 nm according to the procedure of Chance and Maehly (4). A problem with this method is that the orange-red color of the tetraguaiacol fades rapidly (15). To minimize the effects of the fading reaction on kinetic measurements, the initial velocity was estimated by extrapolation as illustrated by the dotted lines of Figure 3. To demonstrate the fading reaction, the enzyme was inhibited with potassium cyanide after color development (Fig. 3). Both the decrease in optical density after adding potassium cyanide and the departure from linear kinetics in the absence of cyanide was due to the fading reaction.

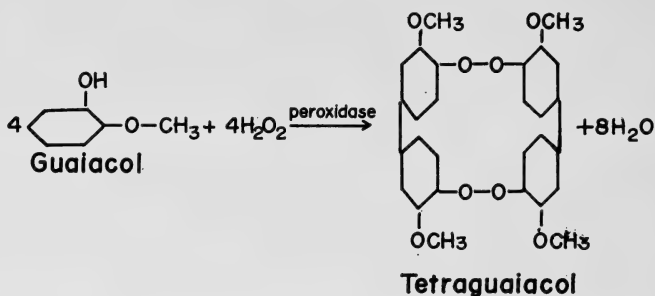


FIGURE 2. Overall reaction of the guaiacol assay for peroxidase activity. In the reaction, 4 moles of guaiacol are oxidized in the presence of 4 moles of hydrogen peroxide to form one mole of tetraguaiacol which absorbs at 470 nm.

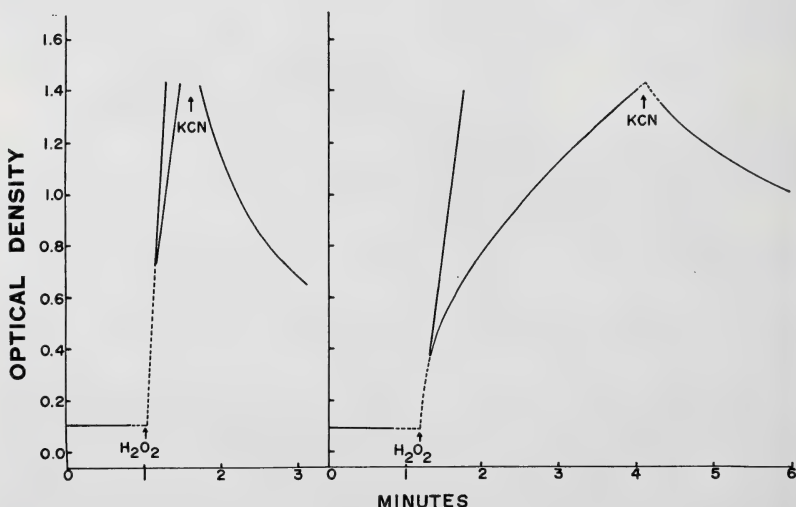


FIGURE 3. Kinetics of tetraguaiacol formation and fading. The initial rate of absorbance change is shown by the dotted line extrapolated back to the time when the reaction was initiated by adding hydrogen peroxide. The gradual departure from linearity is due to fading of the chromogen. After color development, the enzymatic reaction was stopped by addition of cyanide to show the rapidity of the fading reaction. The departure from linearity due to fading was intensified under suboptimal assay conditions. Left: Near optimal conditions of 10 mM hydrogen peroxide and 14mM guaiacol, pH 7.0. Right: 1 mM hydrogen peroxide and 2.5 mM guaiacol, pH 7.0.

The assay for glucose-6-phosphate dehydrogenase was reduction of NADP in the presence of glucose-6-phosphate (11). The reaction was followed spectrophotometrically at 340 nm.

Acid phosphatase was measured by incubating 20 mM *p*-nitrophenyl-phosphate, 50 mM tris-acetate, pH 4.5 and samples of fractions for 15 min. The liberation of *p*-nitrophenol was estimated from the increase in absorbance at 400 nm after addition of 0.2 N sodium hydroxide (2).

Succinic dehydrogenase (succinic-INT-reductase) was assayed by the colorimetric procedure of Pennington (23) with 2-(*p*-indophenyl)-3-(*p*-nitrophenyl)-5-phenyl tetrazolium (INT) as substrate.

All enzyme assays were at room temperature, 25-26° C, under conditions where product formation or disappearance of substrate was proportional to the time of incubation and to the quantity of protein present. Values were corrected for zero time and no-enzyme or boiled enzyme blanks. Protein was determined by the procedure of Lowry *et al.* (14).

Results

When onion stem was incubated for cytochemical detection of peroxidase activities, electron-dense deposits of oxidized diaminobenzidine were observed in the vacuole, on the tonoplast, and in the cell wall (Fig. 4). As in previous studies, including studies with onion (28), peroxidase activity was found to be greatest in young, dividing cells and least in older cells which no longer divided.

Filtered total homogenates were used to investigate the conditions for the peroxidase assay *in vitro* (Figs. 5-8). Figures 5 and 6 show the results of varying peroxide and guaiacol concentration. At 10 mM hydrogen peroxide and 14 mM guaiacol, activity was proportional to protein concentration over a wide range (Fig. 7). Two distinct pH optima, at pH 6.5 and pH 7.0, were found (Fig. 8) as well as shoulders at pH 6.0 and possibly also at pH 7.5. Using citrate buffer, activity was also observed over the pH range 3.5 to 6 with an optimum at 4.5 (data not shown).

During cell fractionation, peroxidase activity of the filtered homogenates was concentrated in the 90,000 × *g* supernatants (Table 1). In contrast to the cytochemical evidence, little activity was associated with any of the particulate fractions. Of the total activity of the filtered homogenates, 80 to 85% was recovered. Of the recovered activity, 3% was particulate and 97% was soluble.

To reconcile the cytochemical findings of compartmentalized peroxidases with the biochemical findings of soluble peroxidases, we studied enzyme solubilization as affected by varying times of homogenization (Fig. 9). Glucose-6-phosphate dehydrogenase, as an example of an enzyme found in the cytosol, and acid phosphatase, as an example of an enzyme thought to be in the vacuole (17), were released most rapidly and reached a maximum in the soluble fraction after 1 min of homogenization. Peroxidases were released more slowly and reached a maximum after about 3 min of homogenization. Peroxidase assayed

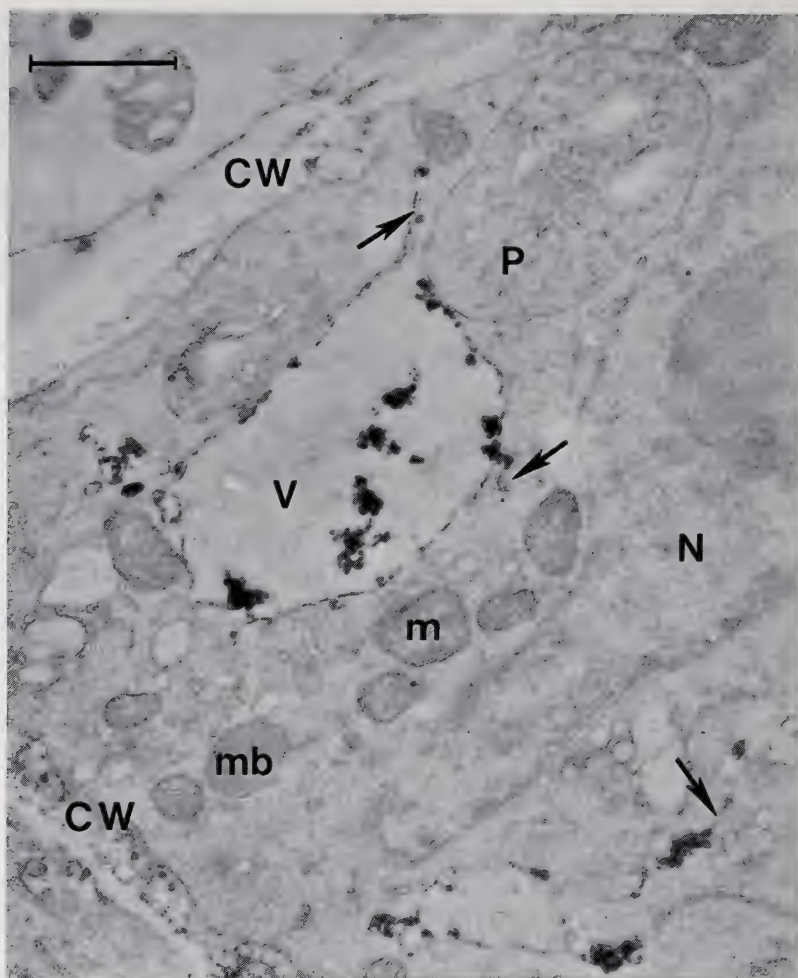


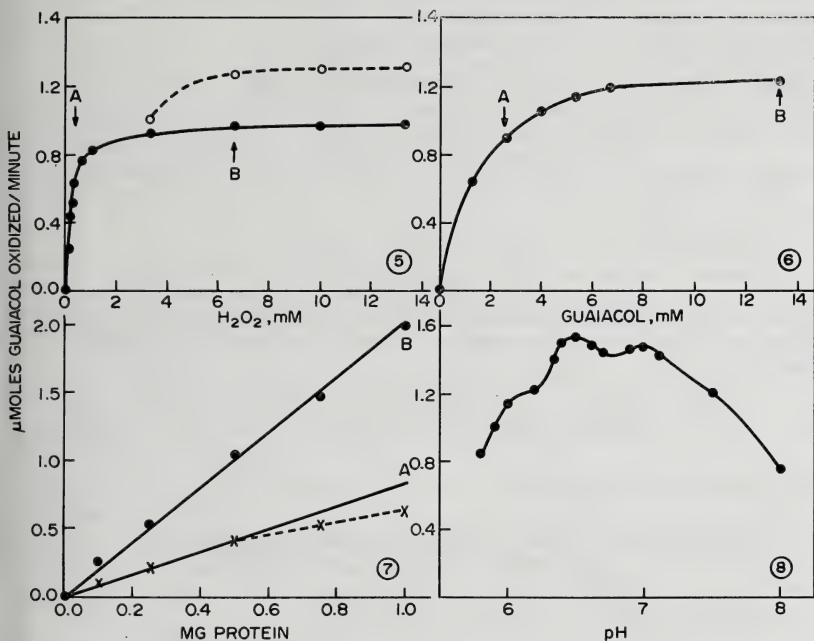
FIGURE 4. *Electron micrograph of a portion of a meristematic cell of onion stem fixed and incubated for peroxidase activity. Electron-dense deposits of oxidized 3,3'-diaminobenzidine were found in the cell wall (CW), vacuole (V) and in flattened cisternae resembling endoplasmic reticulum, which are continuous with the vacuole proper (arrows). In these cells, microbodies (mb) and mitochondria (m) lacked heavy deposits of oxidized diaminobenzidine. P=plastid. N=nucleus. Scale marker=1 μ .*

at pH 6.5 was released more rapidly than the peroxidase assayed at pH 7.0. Succinic dehydrogenase, an enzyme of the inner membranes of mitochondria, was not solubilized by the homogenization procedure (Fig. 9).

Discussion

By cytochemical procedures, peroxidase activity has been found in mitochondria, endoplasmic reticulum, Golgi apparatus, cell walls and vacuoles of plant cells (7, 10, 24). The pH data, as well as those of

others (1, 5, 7, 12, 20), suggest multiple forms or isozymes of peroxidases; Evans (5) reported 12 isozymes for dwarf tomatoes. Our study was initiated to determine whether specific peroxidase isozymes were associated with specific cell components. If so, multiple forms of peroxidase would provide a set of marker enzymes which might help identify plant cell components isolated from cell homogenates. However, in the *in vitro* analyses, the peroxidase activity was largely solubilized by the cell fractionation procedures. No membrane fraction was significantly enriched in peroxidase, and 97% of the recovered activity was present in the post-microsomal supernatant (soluble fraction). This contrasted with the *in vivo* cytochemical findings and with the results for succinic-INT-reductase, a membrane-bound enzyme.



FIGURES 5-8. Characteristics of the peroxidase of filtered homogenates of onion stem: 5) Peroxidase activity shown in relation to peroxide concentration at pH 7.0. The lower curve is at 2.5 mM guaiacol. The upper curve is at 14 mM guaiacol. 6) Peroxidase activity with increasing guaiacol concentration at pH 7.0 and 10 mM hydrogen peroxide. 7) Peroxidase activity is proportional to protein concentration between 0 and 1 mg protein per assay for conditions of guaiacol and hydrogen peroxide marked by the letter B in Figures 5 and 6 and between 0 and 0.5 mg protein per assay for conditions marked by the letter A in Figures 5 and 6. 8) Peroxidase activity as a function of pH. The buffering system consisted of 0.01 M sodium phosphate adjusted with hydrochloric acid. For each determination, the pH was measured at the beginning and at the end of the reaction and remained constant ± 0.1 unit.

To reconcile the *in vivo* and *in vitro* findings, a series of experiments was carried out in which the release of several enzymes was related to the degree of cell homogenization. The results show clearly that peroxidase was solubilized as the tissue was homogenized. The rate of

solubilization was sufficient to release over 50% of the peroxidase in soluble form by the time release of cytoplasmic (glucose-6-phosphate dehydrogenase) and vacuolar (acid phosphatase) contents was complete. The remaining peroxidase was apparently solubilized in subsequent homogenization and/or centrifugation steps to account for the lack of peroxidase in the purified membrane fractions.

TABLE 1. *Distribution of peroxidase activity among isolated cell fractions of onion stem.*

Fraction	Total Activity ¹ (umoles/hr)	Specific Activity (umoles/hr/mg protein)
Filtered Homogenate -----	200	51
0-8,000 X g pellet -----	2.5	0.4
8-90,000 X g pellet -----	3.3	0.5
Gradient fractions: A -----	(0.4) ²	0.3
B -----	(0.4)	0.3
C -----	(0.6)	0.3
D -----	(0.2)	0.3
90,000 X g supernatant -----	160	100

¹ % Recovery = 81.8 ± 2.8 .

% Activity of total recovered in particulate fractions = 3.0 ± 1.8 .

² Numbers in parenthesis refer to subfractions of the 8-90,000 X g pellet recovered from the sucrose gradient of Figure 1. Of the 3.3 units of activity applied to the gradient, 1.6 units were recovered which shows that 50% of the activity was lost or solubilized during the sucrose gradient procedure. All fractions were assayed by conditions A of Figures 5-7.

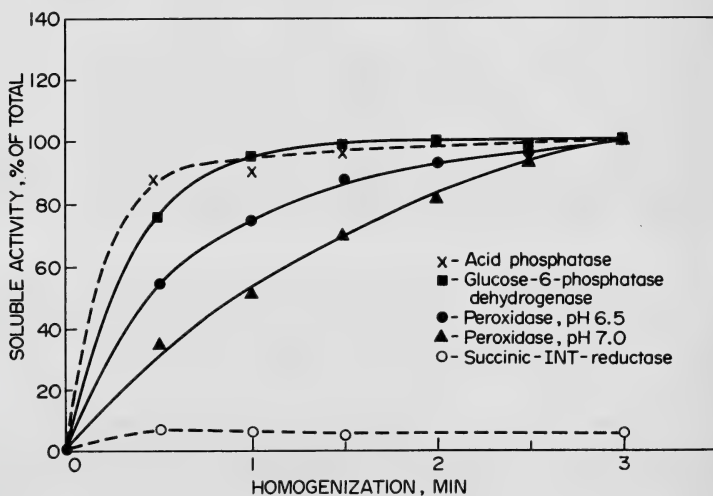


FIGURE 9. *Comparative rate of release of a cytoplasmic enzyme (glucose-6-phosphate dehydrogenase), a presumed vacuolar enzyme (acid phosphatase), an enzyme of the inner membranes of mitochondria (succinic-INT-reductase) and peroxidases at pH 6.5 and pH 7.0 as a function of time of homogenization with the Polytron operated at a constant speed of 5,000 rpm. Soluble activity was determined in the supernatant after centrifugation for 30 min. at 90,000 X g. Peroxidase was assayed according to conditions B of Figures 5-7.*

On the basis of the cytochemical and biochemical findings, we conclude that plant peroxidases are compartmentalized intracellularly but that the bulk of the activity is not tightly bound to membranes or at least is readily released from the membranes. The peroxidases are readily solubilized during cell fractionation, an observation that explains our *in vitro* results but adds a new order of complexity to an already complicated problem. Procedures such as glutaraldehyde fixation prior to fractionation to bind the peroxidase to the membranes or for cross-linking the enzymes within a compartment might provide an interim solution. In any event, it is clear that conventional methods of cell fractionation are unlikely to provide definitive information on the sub-cellular distribution of peroxidases in plants because of the rapid solubilization of the enzymes.

Acknowledgements

We thank Dr. Francis Williamson and Dr. Ian Mather for advice and assistance with the enzyme assays and Prof. Charles Bracker and Prof. A. O. Jackson for helpful discussions. Technical assistance was provided by Keri Safranski and Dorothy Werderitsh.

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A Study of Chloroplast Membrane Polypeptides from Mineral-Deficient Maize in Relation to Photosynthetic Activity¹

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Abstract

Photosynthetic activity and the chloroplast protein distribution patterns on acrylamide gels were studied in micronutrient-deficient maize chloroplasts including boron, copper, iron, manganese, molybdenum, zinc, and all-micronutrient deficiencies. It was found that the chlorophyll concentration was reduced in all deficiencies compared to normal maize chloroplasts. The reaction rates of Photosystem I activity varied among the deficient but Photosystem II activity was reduced in all deficiencies. Non-cyclic photophosphorylation rates were affected most by manganese, zinc, copper, and all-micronutrient deficiencies, but cyclic photophosphorylation rates were most severely reduced by copper, manganese, and all-micronutrient deficiencies. The protein profiles of micronutrient-deficient maize chloroplast proteins were basically similar, with the exception of zinc-deficiency which showed less bands than normal maize chloroplasts and iron and all-micronutrient deficiencies which showed more bands than control chloroplasts. Of the 16-20 chloroplast proteins, five were found to be glycoproteins. The function to structure concept is discussed in relation to maize chloroplasts.

Introduction

Chloroplast proteins have been studied by gel electrophoresis by many investigators (5, 7, 10, 11, 12, 13), but the identification of stained bands with particular components of the electron transport chain has in most cases been tentative. Klein and Vernon (9) using Weber and Osborn's (14) sodium dodecyl sulfate system classified spinach chloroplast proteins according to molecular weight. On this basis they tentatively assign the names of known proteins to gel protein bands within a particular molecular weight range. Thus the correlation between functional chloroplast proteins and electrophoresed protein profiles is only in the beginning stages. In this study we chose a system which would allow us to correlate the knowledge between structure and function with more precision. By studying photosynthetic reactions in various types of micronutrient deficiencies in maize and correlating putative differences in function to differences in protein profiles on gels, we hoped to gain more knowledge about the photosynthetic apparatus in plants.

Materials and Methods

Micronutrient-deficient maize was grown in liquid culture according to Hoagland and Arnon's methods (6) in a controlled climate chamber for 5 weeks prior to chloroplast preparation from leaves with maximum expression of deficiency symptoms. Photosynthetic activity and photophosphorylation assays were performed with freshly prepared chloroplasts, but proteins were isolated from frozen chloroplasts by precipitation with 80, 90 and 100% acetone. Proteins were quantitated by the double biuret assay (15), chlorophyll by Arnon's method (1).

¹ Supported by N.S.F. Grant GB-27501 AI

Photosynthetic reactions (ascorbate and TMPD→methyl viologen for Photosystem I and water→indophenol dye or diphenylcarbazide→indophenol for Photosystem II) were performed as described by Baszynski *et al.* (3) for macro-deficient maize chloroplasts.

Photophosphorylation rates were measured according to Dilley (4) by the acid→base transition method using a pH meter. Chloroplasts for photophosphorylation were prepared in a special medium containing ascorbate and albumin. Non-cyclic photophosphorylation was measured using methyl viologen, cyclic photophosphorylation with phenazine methosulfate in the reaction mix.

Leaf spectra of microdeficient maize leaves (Figs. 1 and 2) were taken with a Unicam SP spectrophotometer against an opal glass standard to reduce scattering as described by Barr *et al.* (2).

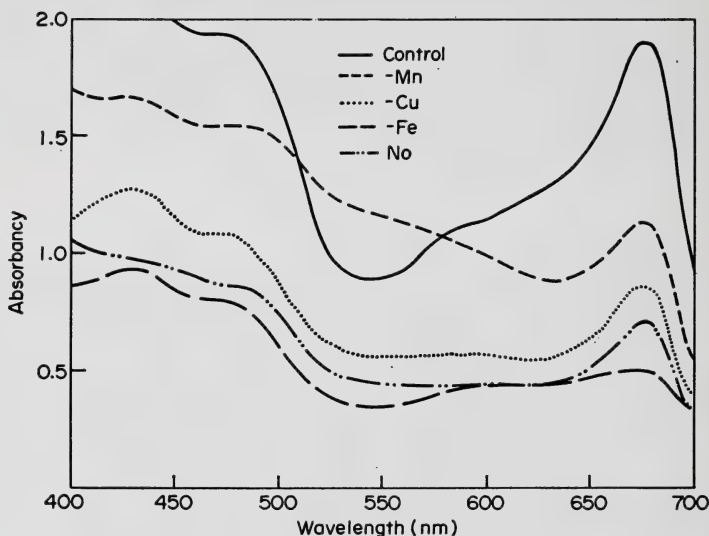


FIGURE 1. Spectra of normal maize leaves compared to spectra of micronutrient-deficient maize leaves.

Gel electrophoresis of chloroplast proteins was done by Hooper's methods (8). Protein bands were stained with Coomassie brilliant blue and destained according to Weber and Osborn (14) in acetic acid, methanol and water. Glycoproteins were identified on gels by the procedure of Zacharius and Zell (16). The reddish glycoprotein bands were found to become obscured by the background within 30 min after destaining. Gel protein band profiles seen in Figures 3, 4, and 5 were obtained by scanning with a Beckman Acta III spectrophotometer equipped with a special gel holder.

Results

Figures 1 and 2 present leaf spectra of normal maize leaves compared to spectra from leaves of various micronutrient deficiencies. The

670-680 nm region shows chlorophyll a peaks. In all deficiencies including boron, copper, iron, manganese, molybdenum, zinc and all-micronutrient deficiencies, the chlorophyll a content is reduced in varying degrees.

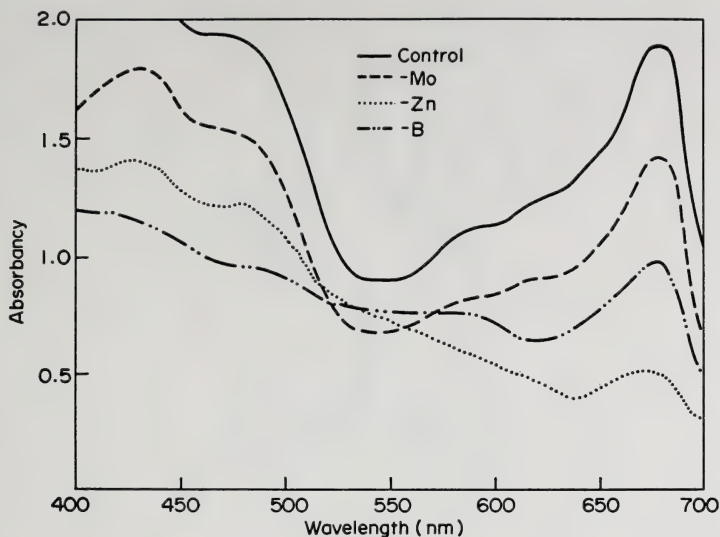


FIGURE 2. Spectra of normal maize leaves compared to spectra of micronutrient-deficient maize leaves.

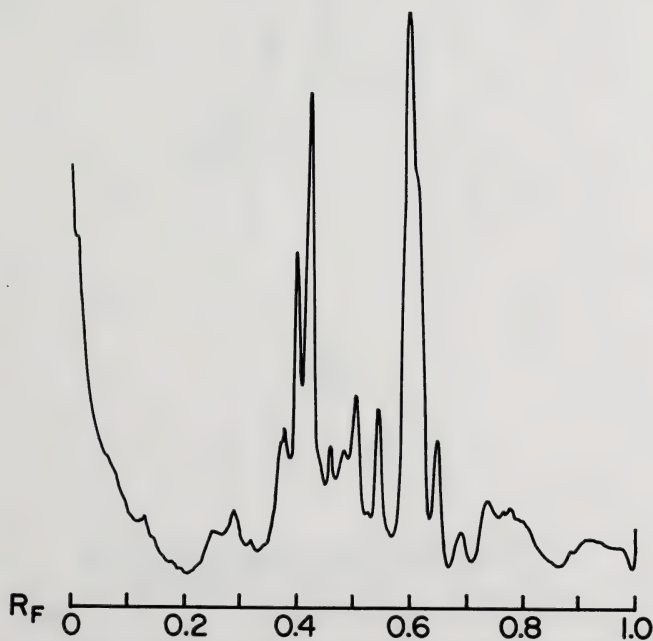


FIGURE 3. A spinach chloroplast protein profile made by densitometer tracing of protein bands after electrophoresis on an acrylamide gel

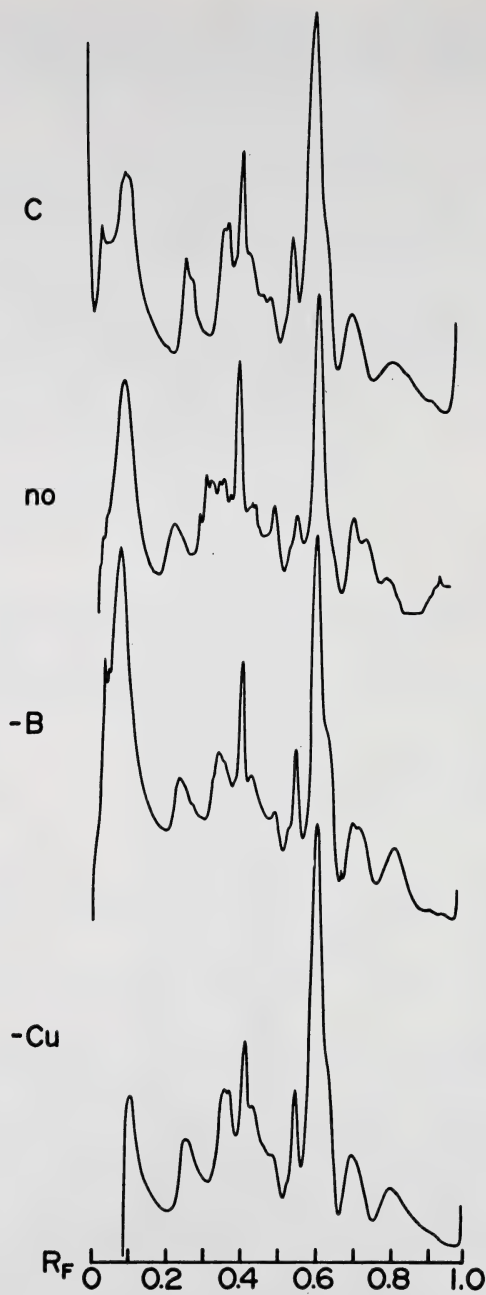


FIGURE 4. A maize chloroplast protein profile from normal and micronutrient-deficient maize leaves.

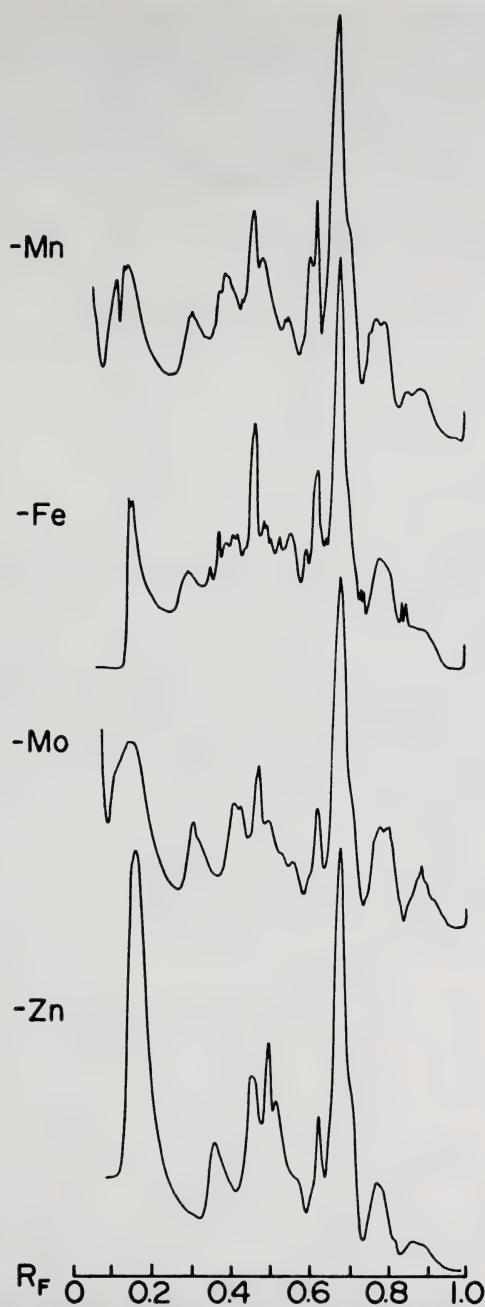


FIGURE 5. A maize chloroplast protein profile from micronutrient-deficient maize leaves.

Table 1 shows the chlorophyll a/b ratios and protein/mg chlorophyll concentration in normal and micronutrient-deficient chloroplasts. Only iron deficiency affects the chlorophyll a/b ratio because less chlorophyll a is synthesized under these conditions. On total chlorophyll basis, the protein concentrations of chlorotic or slightly chlorotic chloroplasts therefore increase giving higher mg protein/mg chlorophyll values in iron, zinc and all-micronutrient deficiencies.

TABLE 1. *Chloroplast protein and chlorophyll content.*

Deficiency	Chlorophyll a/b	Mg protein/mg chlorophyll ¹
Control -----	3.3	6.5
Boron -----	3.3	6.4
Copper -----	2.9	7.8
Iron -----	2.1	10.6
Manganese -----	3.2	8.6
Molybdenum -----	3.3	6.6
Zinc -----	2.9	11.5
No micronutrients -----	3.0	12.0

¹ Ratio given in place of absolute chlorophyll or protein values on dry or wet weight basis because in case of deficiencies very small amounts of functional chloroplasts can be isolated from equal amounts of leaf tissue.

Table 2 reports the photosynthetic reaction rates of normal and micronutrient-deficient chloroplasts. Zinc and all-micronutrient deficiencies lead to decreased, Mn-, Mo-, and B-deficiencies to increased PSI rates. Photosystem II rates either from H₂O→indophenol or diphenylcarbazine→indophenol are reduced in all deficiencies compared to control chloroplast rates.

TABLE 2. *Photosynthetic reaction rates of normal and micronutrient-deficient maize chloroplasts.¹*

Deficiency	umoles acceptor reduced/mg protein/hr		
	PS I		PS II
	Asc. TMPD→M.V.	H ₂ O→DCIP	
Control -----	100	45	51
Boron -----	119	17	19
Copper -----	85	11	13
Iron -----	106	11	14
Manganese -----	131	13	15
Molybdenum -----	124	14	17
Zinc -----	61	8	8
No micronutrients -----	21	5	7

¹ Data by T. Baszynski and J. Brand

Table 3 compares non-cyclic and cyclic photophosphorylation rates in normal and microdeficient maize chloroplasts. Non-cyclic photophosphorylation with methyl viologen is most severely curtailed by Mn-deficiency. Cyclic photophosphorylation, on the other hand, is most

severely affected by Cu-, all-micronutrient, or Mn-deficiency. The most interesting case is presented by Mo-deficiency in which non-cyclic photophosphorylation is decreased but the cyclic rate is increased.

TABLE 3. *Photophosphorylation rates in normal and micronutrient-deficient maize chloroplasts.*

Deficiency	<i>umoles ATP formed/mg protein/hr</i>	
	Non-cyclic with M.V.	Cyclic with PMS
Control -----	4.6	10.5
Boron -----	3.5	12.0
Copper -----	2.6	2.5
Iron -----	4.9	10.2
Manganese -----	1.2	2.9
Molybdenum -----	2.5	15.7
Zinc -----	2.3	5.5
No micronutrients -----	2.6	2.6

Figure 3 presents the chloroplast polypeptide profile obtained by densitometer scanning of a polyacrylamide gel on which spinach proteins have been separated by electrophoresis in an SDS-urea system. Since such a system separates polypeptides by molecular weight, low-molecular weight proteins migrate through the gel faster than high-molecular weight ones. Therefore, the R_F of low-molecular weight proteins approaches 1, while the reverse is true for high-molecular weight proteins. In Table 4 Klein and Vernon's (9) identification of some of the major peaks of a spinach chloroplast protein profile is compared with chloroplast polypeptides from maize within a given R_F range.

TABLE 4. *A Comparison of Klein and Vernon's spinach chloroplast proteins with polypeptides from maize.*

Spinach chloroplast component	Molecular wt. (Kilodaltons)	Maize chloroplasts (R_F range)
Plastocyanin -----	10	0.9-1.0
Ribulose-diphosphate carboxylase -----	12	-----
Coupling factor -----	13	-----
Ferredoxin -----	14	0.8-0.9
Coupling factor -----	17.5	0.7-0.8
Structural protein -----	23	0.6-0.7
Cytochrome f -----	33	0.6-0.7
Coupling factor -----	37	0.5-0.6
Cytochrome b_6 -----	42	0.5-0.6
Transhydrogenase -----	45	0.4-0.5
Ribulose-diphosphate carboxylase -----	56	0.3-0.4
Coupling factor -----	56	0.3-0.4
Coupling factor -----	59	0.3-0.4
Chlorophyll a-bearing protein -----	61	0.2-0.3
Unknown -----	--	0.1-0.2
Unknown -----	--	0-0.1

Four or five of the bands seen in Figures 4 and 5 are associated with the coupling factor. Two of the prominent peaks within the R_F range 0.3-0.4 belong to the coupling factor. This puts them in the range of molecular weights between 50-60,000.

The largest peak seen in Figures 4 and 5 belongs to "structural protein" (R_F 0.6-0.7). In spinach chloroplasts (Fig. 3), normal maize chloroplasts, B-deficient, and Cu-deficient chloroplasts (Fig. 4), as well as in Mn-deficient, Mo-deficient, and Zn-deficient chloroplasts (Fig. 5) there may be a double peak in this R_F range, a part of which appears to contain a glycoprotein (R_F 0.64 in Table 5). As Figures 4 and 5 show, most of the chloroplast polypeptides seen upon SDS gel electrophoresis can be found in varying proportions in all micro-deficient maize chloroplasts. The unique features to distinguish one deficiency from another by densitometer profiles of chloroplast proteins is the occurrence of more bands than normal in iron and all-micronutrient deficiencies, especially in the 0.3-0.5 R_F region. The most significant difference between spinach chloroplast polypeptidase (Fig. 3) and maize chloroplast polypeptides (Figs. 4 and 5) is finding large-molecular weight proteins in maize (R_F range 0-0.2). This is especially striking in Zn- (Fig. 5) and B-deficiencies (Fig. 4).

TABLE 5. *A comparison of normal and micronutrient-deficient maize chloroplast glycoproteins¹*

Deficiency	R_F of major glycoprotein bands				
	0.32	0.49	0.60	0.64	0.67
Control -----	++	+++	+	+++	+
Boron -----	+	++	+	+++	+
Copper -----	++	+	+	+++	+
Manganese -----	++	+++	?	+++	+
Molybdenum -----	+	+++	+	+++	+
Zinc -----	++	++	+	+++	+

¹ These data are contrary to McEvoy and Lynn (J. Biol. Chem. 248:4568, 1973) who found no glycoproteins in spinach chloroplasts.

Discussion

The purpose of this study—to correlate photosynthetic reactions with electrophoretic protein profiles on gels in micronutrient-deficient maize—has been realized only partially. The original premise depended on finding specific differences in photosynthetic reaction rates with each deficiency. As can be seen in Table 2, Photosystem I rates have been affected most severely by the absence of all micronutrients and in zinc and Manganese deficiencies, while photosystem II rates have been reduced in all deficiencies compared to rates in normal maize chloroplasts. Non-cyclic photophosphorylation rates (Table 3) are also greatly reduced in manganese and zinc deficiencies; copper, manganese and the absence of micronutrients influences cyclic photophosphorylation most. Such differences in photosynthetic activity would be expected to correlate with the chloroplast protein distribution patterns but this is not entirely

the case, as seen in Figures 4 and 5. Basically, the gel protein profiles of all micronutrient-deficient maize plants are similar—structural protein (R_F range 0.6-0.7), the major bands of the coupling factor (R_F range 0.3-0.4) the chlorophyll a-bearing protein (R_F range 0.2-0.3), and ribulose-diphosphate-carboxylase (R_F 0.4-0.5) are present in all cases. The most striking difference is shown by zinc-deficient chloroplasts which have less protein bands than normal maize, and by iron and all-micronutrient deficient chloroplasts which show more bands than normal maize. The glycoprotein distribution pattern (Table 5) is also basically the same in all micronutrient-deficient maize plants showing only quantitative differences among the 2 major and 3 minor glycoproteins found in maize. In spinach *versus* maize chloroplasts, maize shows the presence of large-molecular weight proteins (R_F 0-0.2) which are absent from spinach chloroplasts.

Major changes in photosynthetic activity are not correlated with any change in the major polypeptide components of the chloroplast membrane; minor components may change. The loss of function must be more specifically associated with proteins which do not make a large contribution to membrane bulk. Perhaps polypeptides can still be formed and incorporated into the membrane even if a micronutrient prosthetic group is not available. Other effects may be secondary as in the case of boron where a change in metabolic function of the cell may prevent formation of some essential chloroplast component. In this latter situation the micronutrient would not necessarily be found in or function within the chloroplast.

Acknowledgements

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Topography of the Inner Mitochondrial Membrane

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Abstract

Using ferri/ferrocyanide as an artificial electron acceptor and donor the topographical organization of the proteins of the quinol-cytochrome *c* reductase segment of mitochondrial electron transport was studied. Kinetic differences in antimycin-insensitive ferrocyanide oxidase activity and antimycin-sensitive ferricyanide reduction in isolated beef heart mitochondria and electron transport particles indicate a site of interaction on both the outside and inside (M-side) of the inner membrane. Polylysine inhibits ferrocyanide oxidation in mitochondria, but not in electron transport particles. Spectral studies of intact electron transport particles and deoxycholate fractions indicate ferrocyanide reduces cytochrome *c*₁ but not b-type cytochromes. Thus, ferri/ferrocyanide interacts with cytochrome *c* in mitochondria but with cytochrome *c*₁ and possibly another component of electron transport in electron transport particles.

Introduction

An anisotropic organization of proteins in mitochondrial inner membranes has been postulated to provide vectorial proton translocation accompanying electron transport (15, 16, 18). Vectorial proton translocation across a proton-impermeable membrane can result in the formation of a proton gradient of sufficient magnitude to energize the membrane to carry on oxidative phosphorylation or other energy-linked reactions.

Asymmetrical membrane structure has been observed in the inner mitochondrial membrane. Following fractionation of the cristae by detergent and salt, two membranous fractions differing in width, composition, and enzymatic activity are recovered (1, 4, 6). Recombination of the two fractions yields a structurally and functionally intact membrane. Evidence of asymmetric protein localization in the intact inner membrane would support both the chemiosmotic theory and the binary membrane model (3).

The study of membrane topography requires membrane preparations that are homogeneous in particles wholly of one orientation. Intact mitochondria can be isolated that show the physiological orientation, with the 90 Å knobs on the M-side (matrix side) facing the matrix (27). The surface exposed in these right-side out particles is called the C-side. Preparations of electron transport particles (ETP) can be prepared that have an inverted orientation to mitochondria (2), *i.e.* the M-side with 90 Å knobs is exposed while the C-side is on the inside of the membrane vesicle (Figs. 1 and 2).

The topography of the membrane can be elucidated in particles of homogeneous orientation by use of the following techniques: 1) observation of protein location by electron microscopy; 2) covalent bonding of surface proteins with impermeable radioactive surfactants; 3) protein extraction with loss of structure or enzymatic activity and reconstitu-

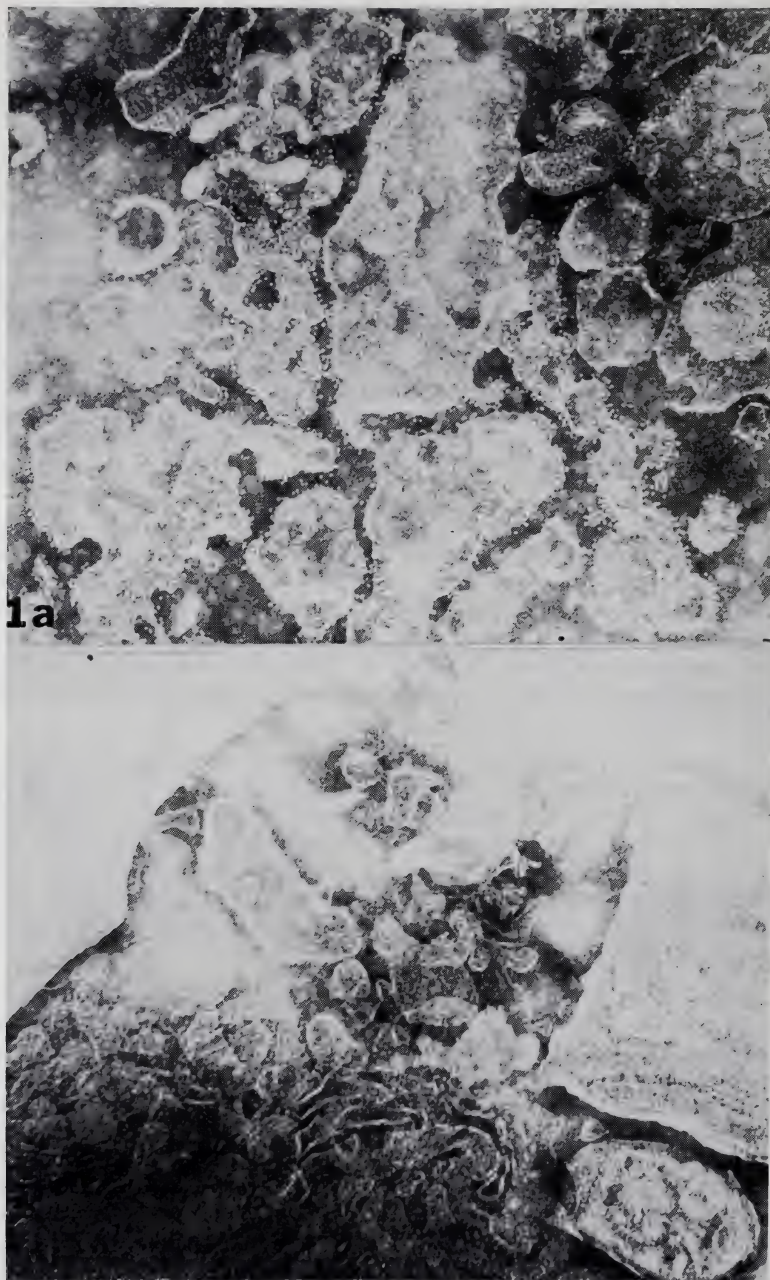


FIGURE 1. A. Negative stained preparation of electron transport particles. B. Negative stained preparation of intact inner mitochondrial membrane vesicles with C-side exposed and 90 Å spheres not visible on the surface. 82,000 X magnification. Unfixed material was stained with 1% phosphotungstate pH 7.0.

tion of structure or activity; 4) inhibition of electron transport or oxidative phosphorylation by impermeable agents, including specific antibody; 5) the use of impermeant donors and acceptors of electron transport. These techniques were used to locate some membrane proteins on either the M-side or the C-side. These data are summarized in Table 1. A third location of a protein, in the middle of the membrane but not necessarily exposed to both M- and C-sides, must also be considered.

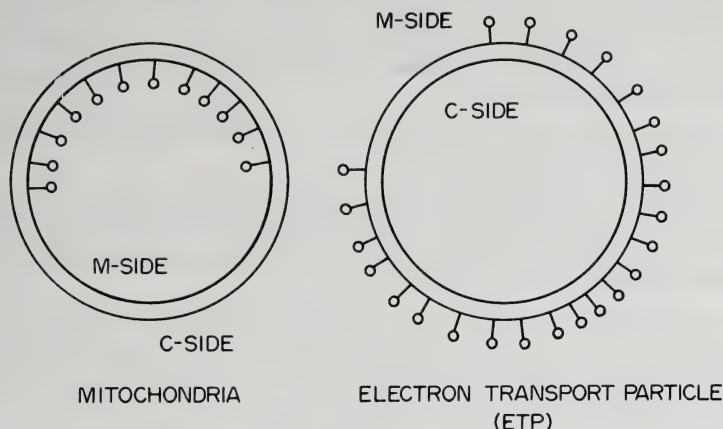


FIGURE 2. Diagrammatic representation of opposite orientations of beef heart mitochondria and electron transport particles.

TABLE 1. Location of inner mitochondrial membrane proteins.

Component	Side	E.M.	Method of Determination				Reference
			Extraction/Reconstitution	Impermeant Donor/Acceptor	Radiolabeled Surfactant	Impermeant Inhibitor	
Cytochrome c	C		X	X	X	X	13, 19, 21, 22, 24
ATPase (F ₁)	M	X	X		X	X	8, 14, 19, 20
Succinate Dehydrogenase	M		X	X			11, 25
NADH Dehydrogenase	M			X			10, 12, 25
Cytochrome a	C			X	Inconclus.	Inconclus.	19, 21, 22
Cytochrome a ₃	?				Inconclus.	Inconclus.	19, 21, 22
Cytochrome c ₁	M			X			7

Using the impermeant electron acceptor/donor ferri-/ferrocyanide (17), cytochrome c₁ was localized on the M-side of the inner membrane. The binding of antibodies against c₁ to mitochondria and the lack of antibody binding to ETP defined c₁ on the C-side of the membrane. Ferricyanide reductions in mitochondria have also suggested c₁ to be on the C-side (5, 9). Recently, cytochrome c₁ was shown to be located on the M-side on the basis of antimycin sensitive ferricyanide reduction

in ETP (7). The present study substantiates the M-side location of c_1 utilizing differences in ferrocyanide oxidation between ETP and mitochondria.

Materials and Methods

Beef heart mitochondria were obtained from fresh heart trimmed of excess connective tissue, minced, and homogenized in 0.25 M sucrose -0.075 M $MgCl_2$ -0.001 M succinate - 0.01 M Na_2HPO_4 . The pH was adjusted with 0.5 M Na_2HPO_4 to achieve pH 7.0-7.2 after homogenization. The homogenate was then centrifuged at 300 x g for 20 min. Mitochondria were isolated from the filtered supernatant by centrifugation at 27,000 X g for 15 min. Mitochondria were washed in 0.25 M sucrose -0.075 M $MgCl_2$ -0.15 M KCl.

ETP were isolated from beef heart mitochondria by the alkaline treatment method of Crane *et al.* (2).

Succinate— $Fe(CN)_6^{3-}$ reductase assays were performed according to Crane *et al.* (2) at 37°C, except that 0.2 μ mole ferricyanide was used with the mixture 50 μ M in succinate. The reaction was monitored at 410 nm on a Gilford spectrophotometer.

Ferrocyanide oxidation was measured polarigraphically in a reaction mixture 83.4 mM PO_4 , 83.4 μ M EDTA and 7.5 mM ferrocyanide. When indicated, 0.2 mg cytochrome c (Sigma, Type III) or 0.2 mg poly-L-lysine (M.W. 70,000) was added.

NADH oxidase or succinic oxidase assays were performed as were ferrocyanide oxidase assays except that either NADH or succinate was added to concentrations of 3.89 mM and 5.56 mM, respectively.

Fractionation of beef heart mitochondria was performed by the method of Wharton and Tzagaloff (26). Difference spectra of the resulting fractions were recorded on a Cary 15 spectrophotometer. Difference spectra of intact ETP were measured on an Aminco-Chance spectrophotometer. Ferricyanide was used to oxidize the reference in all measurements.

Results and Discussion

Homogeneous intact ETP should show no stimulation of NADH or succinate oxidation upon addition of exogenous cytochrome c since the location of cytochrome c is inside the vesicles and the membrane is impermeable to proteins of this size. In contrast, mitochondria should exhibit substantial respiratory stimulation in the presence of external cytochrome c. The ETP used in these experiments show a 6-8% increase in respiration (94% ETP oriented) while the mitochondria exhibit up to a 7-fold increase in respiration after two washes in dilute KCl (14% ETP).

Succinate reduction of ferricyanide in ETP and mitochondria is inhibited approximately 80% by antimycin A, which inhibits electron transport between cytochromes b and c_1 (23). Estabrook (5) has reported the interaction of ferricyanide with cytochrome c in rat liver mitochondria, as has Jacobs and Sanadi (9). However, in intact ETP,

where cytochrome c is sequestered within the vesicle, ferricyanide must be interacting with a component between the antimycin-sensitive site and cytochrome c. Thus the two sites of interaction are different.

TABLE 2. *Ferrocyanide oxidation rates in mitochondria, ETP and purified cytochrome oxidase.*

	uatom 0/mg protein/min		pH
	—cyt c ¹	+ cyt c	
Mitochondria -----	0.06	0.23	7.4
ETP -----	0.56	0.56	7.4
Cytochrome Oxidase -----	0	0.07	8.0

¹ cyt c = cytochrome c

A similar result was observed in the antimycin-insensitive oxidation of ferrocyanide by the cytochrome chain in ETP and mitochondria. As seen in Table 2, ETP catalyze ferrocyanide oxidation at a faster rate than mitochondria. Ferrocyanide oxidation is stimulated by the addition of exogenous cytochrome c in mitochondria but not in ETP. Since cytochrome c is not accessible in ETP, ferrocyanide must be accessible to sites between cytochrome b and c. The sites exposed in ETP could be a non-heme iron component (NHI_{III}) and/or cytochrome c₁. Cytochrome aa₃ does not react directly with ferrocyanide because purified cytochrome c oxidase does not catalyze a significant rate of ferrocyanide oxidation in the absence of cytochrome c.

TABLE 3. *Effective of poly-L-lysine (M.W. 70,000) on ferrocyanide oxidation.¹*

		Polylysine		
		None	0.2 mg	Inhibition
ETP -----	—cyt c ²	0.66	0.74	None
	+cyt c	0.66	0.74	None
Mitochondria -----	—cyt c	0.035	0.02	57%
	+cyt c	0.27	0.04	86%

¹ Data expressed in uatoms 0/mg protein/min

² cyt c = cytochrome c

Further evidence that the site of ferrocyanide interaction is different in ETP and mitochondria is shown in Table 3. The addition of poly-L-lysine to ETP does not inhibit ferrocyanide oxidation. However, polylysine inhibits virtually all cytochrome c stimulated oxidation in mitochondria. These data are consistent with cytochrome c being exposed in mitochondria and thus inhibited by polycationic proteins, as is succinate oxidation (13), but sequestered in ETP. Lack of polylysine inhibition indicates cytochrome c is not directly involved in ferrocyanide interaction with ETP.

Ferrocyanide reduces cytochrome c₁ (reduction peak at 554 nm) in the red fraction following deoxycholate fractionation (spectrum not

shown). The red fraction has been shown to contain most of the cytochromes b, c, and c_1 of the inner membrane (1, 6). That ferrocyanide reacts with cytochrome c_1 and not with b is illustrated in Figure 3, where the difference spectrum of intact ETP displays cytochrome c_1 reduction by ferrocyanide but no reduction of b-type cytochromes (reduction peaks at 563 nm).

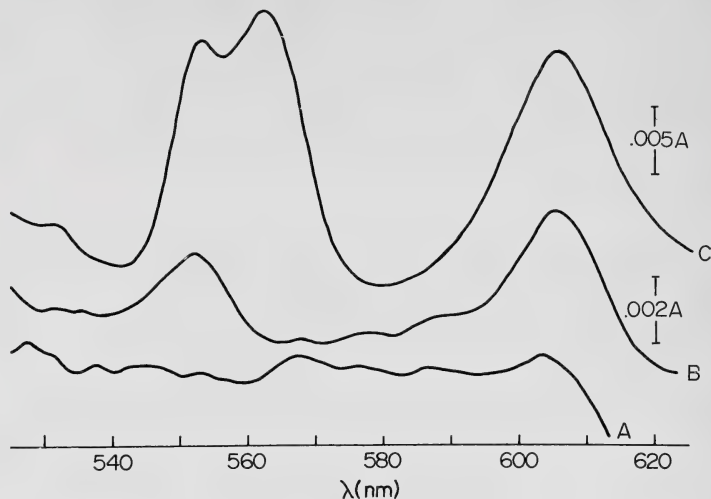


FIGURE 3. Difference spectrum of intact ETP. Ferrocyanide was used to reduce the sample. A. ETP with no ferrocyanide added. B. ETP with 5 μ mole ferrocyanide added. C. ETP sample reduced with $\text{Na}_2\text{S}_2\text{O}_4$. Absorbancy indicated on figure.

Conclusion

The evidence clearly indicates that cytochrome c_1 (and possibly nonheme iron III) is located on the matrix side of the mitochondrial cristae membrane.

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Inhibition by DDT of Calcium Accumulation in Isolated Cell Fractions From Rat Muscle¹

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Abstract

DDT inhibits the accumulation of calcium ions by a sarcoplasmic reticulum fraction of rat muscle. Accumulation was observed in electron micrographs as electron dense deposits of calcium oxalate in membrane vesicles. Calcium accumulation and DDT inhibition were measured using radioactive $^{45}\text{Ca}^{++}$ and spectrophotometric assay techniques. Inhibition of calcium accumulation by DDT occurred at concentrations greater than 0.1 micromolar with maximum inhibition at concentrations greater than 5 μM . Inhibition was most pronounced during the first minute of the reaction. The inhibition of calcium accumulation by DDT may be partly responsible for the loss of muscle control that is characteristic of DDT-poisoned animals.

The toxic effects of DDT [2, 2-bis (p-chlorophenyl)-1, 1, 1-trichloroethane] have been related to alterations in monovalent ion transport (7, 10, 17, 18) especially that mediated by ATPases stimulated by Na^{+} and K^{+} (12, 13, 16, 19). DDT also interferes with processes which involve the transport of Ca^{++} such as egg shell thickening (1, 9, 11) and calcification of surface scales by a marine alga (5). Since fragments of sarcoplasmic reticulum of skeletal muscle accumulate calcium (3, 4), and because this accumulation can be quantitated, we examined the effect of DDT on this system.

Materials and Methods

Cell fractions from the gastrocnemius muscles of male rats (Holtzman Co., Madison, Wis.) were prepared by differential centrifugation according to the method of Martonosi and Feretos (15). Muscle tissue was minced with razor blades and then homogenized with a Polytron homogenizer in a ratio of 5 g tissue per 20 ml of homogenization medium (0.1M KCl, 5 mM histidine pH 7.0, 5 mM dithiothreitol) (22). Myofibrils were sedimented by centrifugation at 1,000 x g for 20 min and the supernatant was centrifuged at 8,000 x g for 20 min. The 8,000 x g pellet was used for the calcium accumulation experiments after resuspension in a solution containing 0.3 M sucrose, 5 mM dithiothreitol, and 5 mM histidine (pH 7.0) to a protein concentration of 2-3 mg/ml (6).

The spectrophotometric measurement of calcium accumulation was according to Fairhurst and Jenden (6). The reaction mixture contained 5 mM potassium oxalate, 20 mM imidazole pH 7.0, 30 mM KCl, 5 mM

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MgCl₂, 5 mM ATP and approximately 50 μ g protein per assay in a volume of 3 ml. After 2 min preincubation, the reaction was initiated by the addition of CaCl₂ (final conc 2×10^{-4} M) and the absorbance change at 350 nm was followed with time at 26° C on a Bausch and Lomb 505 recording spectrophotometer. DDT was added in ethanol or methyl cellosolve (2-methoxy ethanol) solutions with a final concentration of solvent of less than 1%.

Experiments with radioactive calcium ion ($^{45}\text{Ca}^{++}$, 0.5 mCi/mM) were performed with the same reaction mixture as the spectrophotometric assays except that the amount of protein was 0.2 to 0.3 mg per reaction mixture. The reaction was started by the addition of a mixture of radioactive and nonradioactive CaCl₂ and was terminated by filtration through 0.45- μ Millipore filters followed by five 1-ml washes with nonradioactive 0.1 M CaCl₂. The filter containing the washed sarcoplasmic reticulum fragments was then placed in Bray's solution (2) and radioactivity was measured on a liquid scintillation counter. Protein was measured according to the method of Lowry *et al.* (14).

Pellets of sarcoplasmic reticulum were prepared for electron microscopic examination by subjecting reaction mixtures with and without CaCl₂ to centrifugation. The membrane pellets were fixed in 2% glutaraldehyde in 0.05 M cacodylate buffer pH 7 followed by 1% OsO₄ in the cacodylate buffer. The pellets were then dehydrated in an acetone series and embedded in Epon 812 (21). Sections were either stained with lead citrate (20) or left unstained and examined and photographed with a Phillips EM 200 electron microscope.

Results

Membrane vesicles of the sarcoplasmic reticulum fraction showed only scattered accumulations of electron-dense materials when incubated in the absence of calcium (Fig. 1A, lead stained). In the presence of calcium, holes bounded by a membrane appeared in the sections (Fig. 1B, lead stained). When the sections were not lead-stained, some membrane vesicles contained electron-dense deposits (Fig. 1C). The presence of the insoluble calcium oxalate precipitates inside the vesicles provided the basis for the isotope and spectrophotometric assay techniques used in this study and identified the vesicles as sarcoplasmic reticulum.

The accumulation of calcium (as $^{45}\text{Ca}^{++}$) by sarcoplasmic reticulum membranes required adenosine-5'-triphosphate (ATP) as an energy source (Fig. 2). Almost no activity was measured during the first minute of the reaction with guanosine-5'-triphosphate (GTP) or uridine-5'-triphosphate (UTP); whereas accumulation was extensive in the presence of ATP. Calcium accumulation was markedly inhibited during the first minute of the reaction by 8.4 μ M DDT and the lag in uptake was more pronounced with 17 μ M DDT (Fig. 3). After the initial lag, accumulation occurred and eventually reached the control level (data not shown).

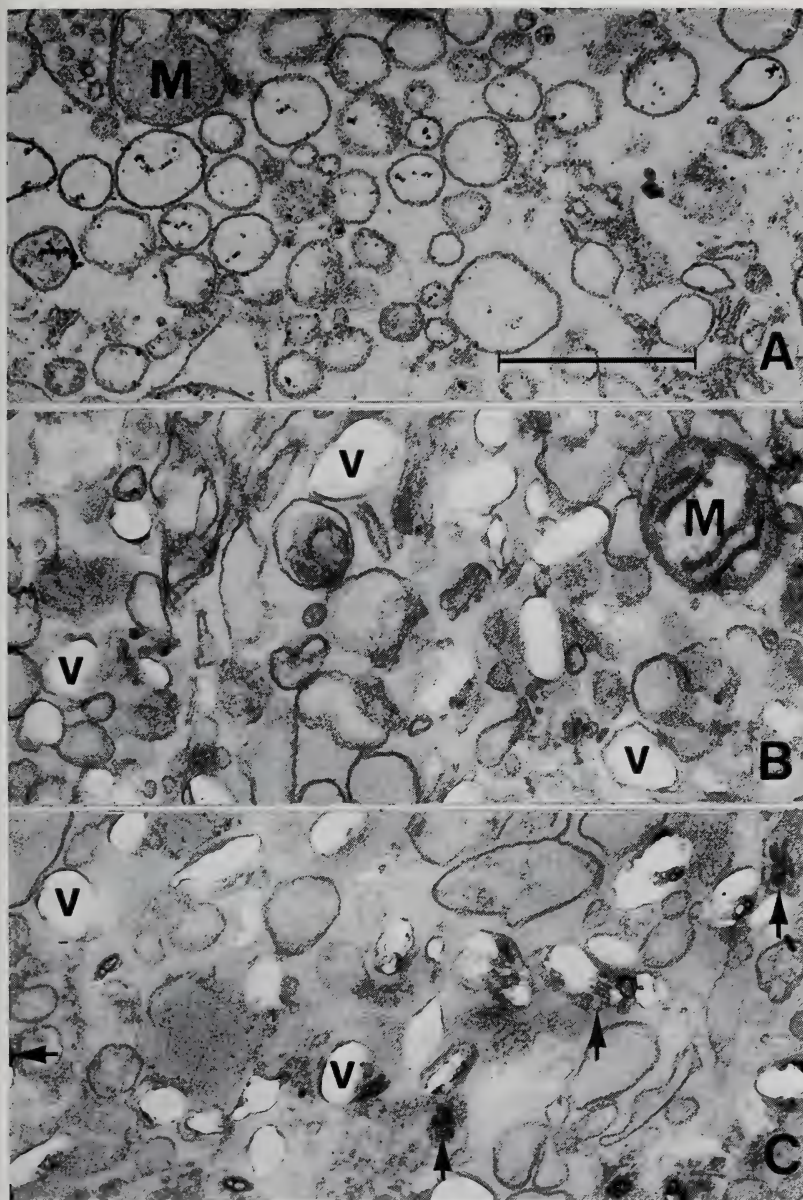


FIGURE 1. Electron micrographs of sarcoplasmic reticulum fractions sedimenting at 8,000 X g. A. Fraction incubated in the absence of CaCl_2 . Section stained with alkaline lead citrate. B. Fraction incubated in the presence of 0.2 mM CaCl_2 . Section stained with alkaline lead citrate. Holes surrounded by membranes result from loss of calcium oxalate deposits from the sarcoplasmic reticulum vesicles (V). C. As in B except the section was not stained with alkaline lead citrate. Here, electron-dense deposits (arrows) of calcium oxalate are seen inside some of the membrane vesicles. M=mitochondrion. Bar=0.5 μ .

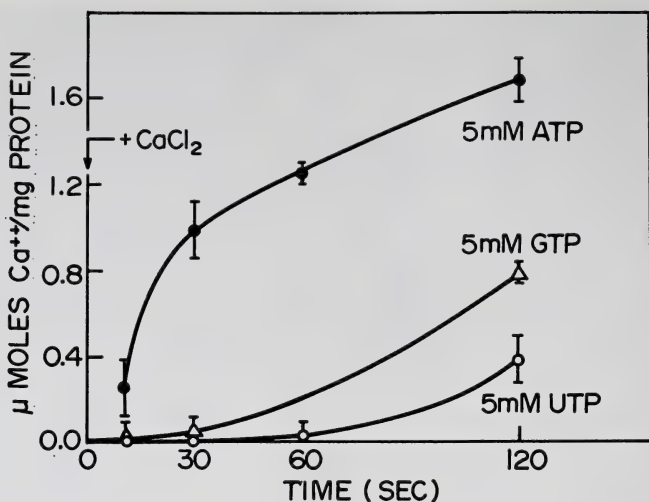


FIGURE 2. Calcium accumulation by the sarcoplasmic reticulum fraction in the presence of 5 mM ATP, GTP or UTP. CaCl_2 containing $^{45}\text{CaCl}_2$ was added at $t=0$. Samples were removed and the membranes were collected by Millipore filtration. Results are the average of two determinations $\pm$ mean absolute deviations.

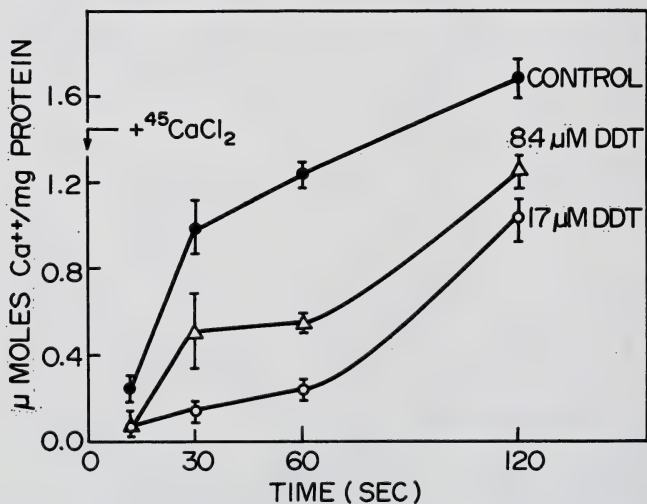


FIGURE 3. Calcium accumulation by the sarcoplasmic reticulum fraction. The procedure was as in Figure 2 except that DDT was added as indicated.

Spectrophotometric analyses verified that DDT inhibited accumulation of calcium by sarcoplasmic reticulum vesicles (Fig. 4). Again, inhibition by DDT was most pronounced during the first minute of the reaction. A plot of the calcium accumulation ($\Delta\text{O.D.}$ after 1 min.) versus the logarithm of the DDT concentration (Fig. 5) showed no

inhibition at concentrations below $0.1 \mu\text{M}$ (10^{-7} M). Inhibition occurred between $0.1 \mu\text{M}$ and $5 \mu\text{M}$ DDT and reached a maximum near $5 \mu\text{M}$ DDT. Increasing the DDT concentration above $5 \mu\text{M}$ did not increase the degree of inhibition.

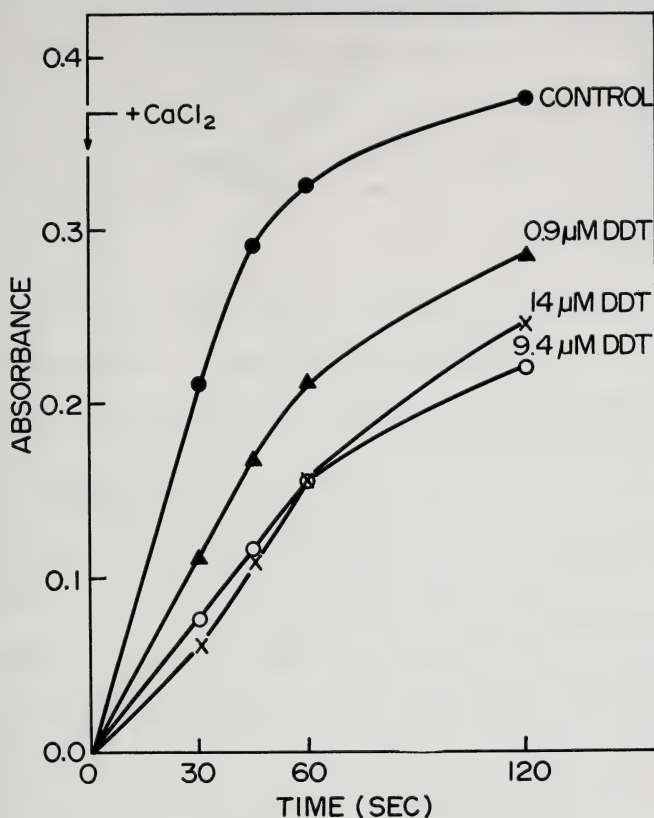


FIGURE 4. Calcium accumulation by the sarcoplasmic reticulum with and without DDT. Activity was monitored by the change in absorbance at 350 nm.

Discussion

The electron micrographs of the sarcoplasmic reticulum fraction incubated in the presence of calcium show that electron-dense precipitates formed inside many of the membrane vesicles (Fig. 1). We interpret the micrographs as showing that the membrane vesicles accumulate calcium ions which form insoluble deposits of calcium oxalate. The calcium oxalate is responsible, in turn, for the electron dense deposits (Fig. 1C), and the holes in the sections from which deposits have been lost (Figs. 1B and 1C, see also ref. 5).

The results of the radioactive and spectrophotometric assays show that DDT inhibits the accumulation of calcium by sarcoplasmic reticulum fractions. The major inhibition appears in the early part of the re-

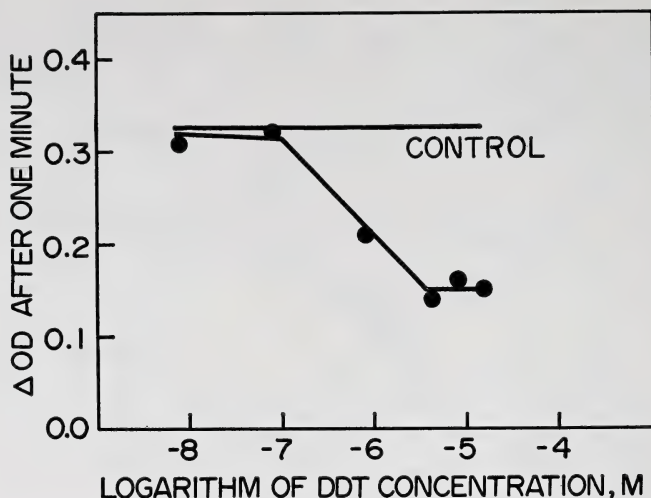


FIGURE 5. Change in absorbance at 350 nm after 1 min vs. the logarithm of DDT concentration. Control activity is after one minute in the absence of DDT.

action (Figs. 3 and 4). The initial lag in accumulation may be significant since proper muscle contraction and relaxation are dependent upon rapid transport of calcium ions by the sarcoplasmic reticulum (3, 4, 8). If the rate of accumulation of calcium ions were reduced, relaxation of the muscle would also be slowed sufficiently to potentiate the muscle twitching symptom of DDT toxicity.

The inhibition of calcium accumulation by DDT is characterized by threshold dose dependency (Fig. 5). At concentrations below $0.1 \mu\text{M}$ there is no apparent effect and at concentrations of $5 \mu\text{M}$ or greater inhibition is maximal. This range of inhibition is similar to that for the inhibitory effect of DDT on ATPases of synapses noted by Matsumura and Patil (16). Thus the active, membrane-associated transport of calcium by sarcoplasmic reticulum of muscle cells is inhibited by DDT. The inhibition is expressed as a lag in the initial uptake of calcium and occurs at DDT concentrations similar to those which inhibit other ion transport systems. The results suggest that DDT interferes with membrane associated calcium transport to cause ataxia in poisoned animals.

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We wish to thank Dorothy Werderitsh and Keri Safranski for excellent technical assistance.

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CHEMISTRY

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ABSTRACTS

Why Square Planar Complexes Exist. LINDA S. HILL and ERWIN BOSCHMANN, Department of Chemistry, Indiana University-Purdue University at Indianapolis, Indiana 46202.—An important characteristic of coordination complexes (AB_x) is the coordination geometry. Symmetry considerations, steric factors, and electronic repulsions alone can often correctly predict the geometry of a complex, *i.e.*, AB_2 and AB_3 systems are expected to be of linear and trigonal planar geometries, respectively. But the AB_4 system is different in that two configurations, tetrahedral and square planar, are possible. Based on steric or electronic repulsions, only tetrahedral complexes should exist. However, a number of transition metals prefer the planar configuration. For these cases, barring steric limitations, crystal field stabilization energy (CFSE) becomes the important feature in structure determination. This aspect of theoretical inorganic chemistry is all too often dismissed with brief statements such as 'd⁸ electronic configurations are more likely to form planar complexes', or 'the scale is tipped in favor of a square configuration at d⁸ due to large CFSEs'. These vague arguments do not adequately explain for instance why $NiCl_4^{2-}$ a d⁸ system, is tetrahedral while $Ni(CN)_4^{2-}$ is planar, or why some d⁷ and d⁹ systems also have planar configurations. We have found it instructive to treat this point by preparing carefully chosen plots of CFSE *differences vs.* 'd' electron population. Not only can the structures of existing AB_4 complexes be clearly understood, but the structures of as yet unknown AB_4 species can be predicted as well.

Rhenium (I) Complexes of 2-Cyanophenyldiphenylphosphine. BRUCE N. STORHOFF and ANTHONY J. INFANTE, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Novel, Re(I) derivatives of 2-cyanophenyldiphenylphosphine (L) have been isolated in good yields from the reactions of $Re(CO)_5X$ ($X=Cl, Br$) with L in refluxing benzene. These derivatives are stable and colorless, but, unfortunately, nearly insoluble in all organic solvents. The stoichiometries have been established as $(Re(CO)_3LX)_n$ from elemental analyses. Thorough infrared and Raman spectroscopic studies of these molecules indicate that for both, the CO groups are in a *fac* arrangement around the metal center. In addition, these studies indicate that L functions as a bidentate bridging ligand rather than as a bidentate chelating ligand.

The Stereochemistry of Reactions at Carbon Transition Metal σ -Bonds. P. L. BOCK, Department of Chemistry, Ball State University, Muncie, Indiana 47306, and G. M. WHITESIDES, Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.—The use of the stereospecifically 1,2-dideuterated 3,3-dimethylbutyl grouping as a stereochemical probe is discussed. Convenient syntheses of the parent compounds *threo*- and *erythro*-3,3-dimethylbutan-1-ol-1,2- d_2 (1) are described. Reactions of the *p*-bromobenzene sulfonate esters of 1 with $C_5H_5Fe(CO)_2$ — yields alkyliron compounds with >95% inversion of configuration at carbon. The stereochemical results for halogenation, oxidation, thermal decomposition and insertion reactions of the alkyliron species are presented.

Synthesis and Catalytic Properties of a Cyclic Octapeptide. MARJORIE SVOBODA and R. W. ROESKE, Department of Biochemistry, Indiana University Medical Center, Indianapolis, Indiana 46202.—The cyclic octapeptide, cyclo lysyl glycyl *p*-aminobenzoyl glycyl histidyl glycyl *p*-aminobenzoyl glycyl, has been synthesized by the solution technique. This peptide was designed to have some of the characteristics of an enzyme: a hydrophobic cavity for substrate binding, a histidine residue as a catalytic site and a charged group, the protonated ϵ amino group of lysine, to enhance solubility in water.

To ascertain the catalytic properties of this peptide, a number of substrates were synthesized; the nitrophenyl esters of *t*-butoxycarbonyl glycyl *p*-aminobenzyl glycine, *t*-butoxycarbonyl glycyl (valyl) gamma amino butyryl glycine, *N* succinyl 11 aminoundecanoic acid, 2,4 dinitrophenyl lysyl glycine, and carbobenzoxy glutamyl glycine. These esters were designed to fit the hydrophobic cavity of the cyclic peptide to properly position the ester carbonyl with respect to the histidine imidazole nitrogen.

The hydrolysis of the esters in phosphate buffer at pH 7 was followed by the change in absorbance at 400 nanometers with the Cary 14 Spectrophotometer. K_{cat} values for the cyclic peptide catalyzed hydrolyses were compared with those obtained for imidazole and a small histidine peptide. It will be attempted to correlate the kinetic results with interactions between the cyclic peptide and substrate molecules.

Syntheses and Binding Properties of Cyclic Hexapeptides Containing *CIS*-4-Aminocyclohexane Carboxylic Acid. S. M. KALBAG and R. W. ROESKE, Department of Biochemistry, Indiana University Medical Center, Indianapolis, Indiana 46202.—Cyclohexaamylose has been studied extensively as a model for a hydrophobic binding site of an enzyme, by M. Bender, F. Cramer and others. Attempts to modify cyclohexaamylose by replacing one or more of the hydroxyls by amino, sulfhydryl or imidazole groups have not been very successful. We synthesized a series of cyclic peptides that resemble the cycloamyloses in size and shape. The peptides consist of four or five residues of *cis*-4-aminocyclohexane carboxylic acid (Acc) or *cis*-4-hydroxycyclohexane carboxylic acid (Hcc).

The following cyclic peptides have already been synthesized (I through III), and synthesis of IV is in progress.

Lys (Acc) ₅	I
Lys Acc Acc Gly Acc Acc	II
Lys Acc Hcc Gly Acc Hcc	III
Lys Gly (Acc) ₄	IV

The following intermediates have been synthesized and used in synthesizing above peptides.

Boc	
Z-Lýs (Acc) ₅ -OBz	V
Boc-Gly-Acc-Acc-Lýs-Acc-Acc-OBz	VI
Boc	
Z-Lýs (Acc) ₄ Gly-OBz	VII
Boc-Acc-Hcc-Gly-Acc-Hcc-OBz	VIII
Boc	
Z-Lýs-Acc-Acc-Gly-Acc-Hcc-OBz	IX

Interesting problems were involved in the synthesis of II and IV, which were presented.

For binding studies 1-(p-bromophenyl)-1-cyanoacetic acid is synthesized and its rate of decarboxylation is planned to be studied in the presence and in the absence of the above cyclic peptides (I through IV).

Reaction Mechanism of Benzylpenicillin with 2-Mercaptoethylamine.

DAVID R. HOGUE and EUGENE S. WAGNER, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Penicillin is known to be inactivated by cysteine and related 2-mercaptoamines. An earlier study, using polarimetric methods, proposed that 2-mercaptoamines with a free sulphydryl and amino group on adjacent carbon atoms formed an intermediate thioester with the carbonyl group of the β -lactam of penicillin. It was proposed that the thioester had been formed by an intramolecular rearrangement via a S $\rightarrow$ N acyl transfer to give penicilloyl-amide. This study re-examines the reaction of benzylpenicillin with 2-mercaptoethylamine at 30°Centigrade and pH 7.5. The progress of the reaction was followed using nuclear magnetic resonance. The spectra obtained indicate that benzylpenicillin reacts directly with 2-mercaptoethylamine, with no evidence of a thioester intermediate or S $\rightarrow$ N acyl transfer.

Synthesis and Cope Elimination of N-(2-Deuteroethyl)-N-ethyl aniline oxide.

WILLIAM E. GROVES and TERRY L. KRUGER, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—The title compound was prepared by lithium aluminum hydride reduction of N-ethyl-N-trideuteroacetanilide followed by peracid oxidation. Good yields were obtained in each step. Analysis by nuclear magnetic resonance and infrared was used to verify the structures. A value for k_H/k_D in the Cope Elimination was presented.



The Polonovski Reaction of Substituted-N,N-diethylaniline Oxides. TERRY L. KRUGER and HARRY F. BANEY, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—The reaction of acetic anhydrid with substituted-N, N-diethylaniline oxides yields: N,N-diethylanilines, N-ethylanilines, and N,N-diethyl-*o*-acetoxyanilines. The reaction is very rapid—occurring in seconds even at low temperatures. The ratios of products are dramatically solvent dependent. The products have been successfully analyzed by glpc and the progress of the reaction monitored by nuclear magnetic resonance. No evidence (chemically induced dynamic nuclear polarization CIDNP) for free radical pathways to the major products can be found. Product ratios and their solvent dependence can be interpreted by present polar and electrocyclic mechanisms.

Temperature Dependence of the Surface Tensions of Aqueous n-Heptanol Solutions. EUGENE SCHWARTZ and SPENCER K. PORTER,¹ Department of Chemistry, DePauw University, Greencastle, Indiana 46135.—A Du Nouy tensiometer was modified for precise temperature control and used to measure surface tensions of aqueous n-heptanol solutions. The temperature range was 10° to 30° Centigrade, and the concentration range was very dilute to saturated. Each set of surface tension *vs.* temperature data was fitted to a second order virial equation by least squares.

A thermodynamic analysis using the Gibbs-Helmholtz equation gave ΔG , ΔS , and ΔH for the virtual process of transferring material from the bulk of the solution to its surface. It was found that ΔS for this process was positive and independent of concentration, and that ΔH decreased with increasing concentration at constant temperature.

The Gibbs adsorption isotherm was used to calculate surface excesses and to estimate the area of the surface per heptanol molecule. These ranged between 24.5 and 69. square Angstroms. The former value is slightly above the minimum of 21.5 square Angstroms found by Langmuir and others in their studies of insoluble monomolecular films.

The Comparison of Calcium Hydroxide and Sodium Hydroxide for Chemical Processing Liquid Wastes Control and Purification. ROBERT H. L. HOWE, Eli Lilly and Company, Tippecanoe Laboratories, Lafayette, Indiana 47902.—The physical and chemical advantages and disadvantages of calcium hydroxide and sodium hydroxide for chemical and biochemical processing liquid wastes control and purifications were compared and discussed.

Physical and Chemical Evaluation of Used Motor Oil. ROSS C. KOILE and ROBERT E. VAN ATTA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Crankcase oil samples were removed at intervals from a test vehicle during extensive urban and highway driving and subjected to various physical and chemical tests. The mechanical

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condition of the vehicle was inspected and monitored throughout the study, which was designed to develop a simple and inexpensive, though scientifically accurate, method for evaluating the condition of crankcase oil so that the necessity for an oil change could be reliably determined. Viscosity, refractive index, acidity, infrared spectrophotometric and gas chromatographic data were reported. Correlations were drawn between the test results and the type of traffic, normal engine function, mechanical condition of the test vehicle, and the operational life of the oil. Possible applications of the tests to fleet scale operations were discussed.

Diffusion of Ca^{++} , Mg^{++} , and Pb^{++} and their Interaction with Precipitated Amino Acid Barriers. ANN C. WORTHINGTON and JOHN H. MEISER, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Diffusion coefficients of Ca^{++} , Mg^{++} , and Pb^{++} were determined in agar solutions at room temperature. Precipitate bands similar to those observed in Liesegang phenomena were formed by each of the above ions with various amino acids or their derivatives. The motion of the two ions not included in the band were studied in relation to their interaction with the band. A brief discussion of the techniques and of the results was given.

High Resolution Mass Spectrum of Non-Vicinal $^{13}\text{C}_2$ Labeled Tropylium Iodide. ALAN SIEGEL, Department of Chemistry, Indiana State University, Terre Haute, Indiana 47809.—One of the most intriguing and important findings in the field of mass spectrometry has been the discovery by Meyerson and co-workers that the C_7H_7^+ ion derived from toluene and related species is not the familiar benzyl ion but rather a more symmetrical species, *viz.*, the tropylium ion. C-13 and deuterium labeling data have established thus far that the C_7H_7^+ ion formed is best represented by a tropylium ion in which the carbon atoms have all lost positional identity with respect to their toluene origin. In an effort to determine whether the observed rearrangement in toluene occurs before or during the primary cleavage (loss of hydrogen) or whether skeletal reorganization also occurs in the tropylium ion itself, a non-vicinal $^{13}\text{C}_2$ tropylium salt was synthesized and its high-resolution mass spectrum recorded.

Radiocarbon Dating of Indian Site Remains of Indiana. R. JACK BINNION and JOHN H. MEISER, Department of Chemistry, and DAVID E. KOLTENBAH, Department of Physics, Ball State University, Muncie, Indiana 47306.—A sample of charcoal from an Indian pit site of Indiana was used to demonstrate the method of determining the age of a sample through radiocarbon dating. This paper concentrated on the calculation of data once liquid scintillation counting gives a measure of the radioactivity in the sample. Included in this discussion was the use of a "modern" carbon sample to determine a reference date, thus eliminating the effects of atomic atmospheric testing. Details of the experimental procedure were given in a paper presented by Lepera, Kolténbah and Meiser (see the Physics Division). Findings concerning the age of the sample were presented.

Computer Simulation of Titration Curves. CLAUDE EDWIN WILSON, Department of Chemistry, Indiana-Purdue University at Indianapolis, Indiana 46205.—The theory used to generate the titration curves makes no approximations except that equilibrium is obtained and that activity corrections can be neglected. The method yields an algorithm that is easily incorporated into a program to calculate the points. The output consists of the calculated points and an approximate plot using the line printer. Examples were given for the titration of simple acids, polyfunctional acids, edta and acids titrated with sodium hydroxide contaminated with carbon dioxide. The use of such curves in the teaching of analytical chemistry was discussed.

Titration Errors Arising from the Use of Gran Plots with Experimentally Obtained Data from a Strong Acid-Strong Base Titration. STANLEY L. BURDEN and DAVID E. EULER, Chemistry Department, Taylor University, Upland, Indiana 46989.—Endpoints for six titrations of 100.00 milliliters of 0.01 normal HCl with 0.09956 normal NaOH were determined both by phenolphthalein color change and by Gran plots and compared. The pH was measured at 1.00-milliliter increments of added titrant until 17.00 milliliters of titrant had been added. Several techniques were investigated to optimize the precision and accuracy of the endpoints obtained from the Gran plots. The best results were obtained when only data taken after the endpoint were used and when the parameter $2.303RT/nF$ was varied until the best linear fit using the least squares method was achieved. Agreement with phenolphthalein endpoints ranged from -0.31 per cent when seven data points were used to $+1.15$ per cent when three data points taken immediately following the endpoint were used. The relative average deviation among the six endpoints in each set of data ranged from $+0.54$ per cent to $+0.67$ per cent. A $+0.18$ per cent relative average deviation among the corresponding phenolphthalein endpoints was observed. When data preceding the endpoint were used in the Gran analysis the effects on the titration error arising from the number and spacing of data points were found to agree with predictions reported in an earlier theoretical study. These effects were reduced when data taken after the endpoint were used in the Gran analysis.

An Experiment in Practical Polarography—Determination of Zinc and/or Manganese in Magnesium Alloys. GLENN A. SHERWOOD and ROBERT E. VAN ATTA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—An experiment was described which introduces the student to polarography via the usual qualitative measurements and direct comparison, pilot ion, and standard addition quantitative methods, as well as the effects of maximum suppressors, buffer-electrolytes, and most other conventional direct current voltammetric techniques. The experiment involves the analysis of an industrial magnesium-base alloy (such as Dowmetals) for its zinc and/or manganese content in the range of 0.25 to 1.06 per cent, with an average accuracy of ± 5 relative per cent. The experiment may be completed in approximately 2 hours with easily constructed manual apparatus or with any commercially available instrumentation.

Synthesis and Characterization of Penicilloyl-Poly-L-Cysteine: A Possible Skin Test Reagent for Penicillin Allergy. DIANA F. STORHOFF and EUGENE S. WAGNER, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Penicilloyl-poly-L-lysine is the most commonly used skin test reagent for penicillin allergy, but varies markedly in its reliability. We believe that penicillin, or the more reactive derivative penicillenic acid formed *in vivo*, reacts with thiol groups of proteins rather than amino groups to elicit the major/minor allergic response. Kinetic and spectral studies indicate that the synthesis of penicilloyl-poly-L-cysteine was accomplished by the reaction of benzylpenicillenic acid with poly-L-cysteine under physiological conditions and could serve as a skin test reagent for penicillin allergy.

Development of an Automatic Recording Apparatus for Gasometric Analyses at Constant Pressure

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Abstract

Rate studies on the evolution of carbon dioxide from diortho-substituted benzoic acids in hot, strong sulfuric acid have in the past been carried out with a manually operated apparatus. To improve the quality of the data obtained, an automatically operated recording apparatus was designed and built which would produce a continuous record of the carbon dioxide evolved as a function of time at constant pressure. The automatic gasometric apparatus was calibrated and applied in a preliminary fashion to kinetic studies of the decarboxylation reaction. Computer plots show that the reaction follows first order kinetics with individual points having good precision.

The kinetics of the acid-catalyzed decarboxylation of diortho-substituted benzoic acids has been under investigation for a number of years. In sulfuric acid concentrations of 70-90% and in the temperature range of 60°-100°C, mesitoic acid yields mesitylene and carbon dioxide (1), and duroic acid goes to durene and carbon dioxide (2), both reactions proceeding smoothly to completion. These reactions were run in a closed system under conditions of constant pressure and temperature, with the increase of volume due to the evolved carbon dioxide counteracted by manually draining liquid from a buret sealed into the system. The volume of liquid removed was measured as a function of time, yielding rate data which could be analyzed in the study of the reaction mechanism. The chief difficulties with the manual gasometric technique have been (a) variations in operator technique making reproducible data hard to obtain, and (b) unavoidable slight variations in internal pressure which affect the solubility of carbon dioxide in the sulfuric acid reaction medium. A gasometric apparatus has therefore been designed which permits collection of data automatically and with smaller variations in internal pressure.

Recently a constant volume variable pressure gasometric apparatus was designed by Timberlake and Martin (3) which permitted automatic data collection. The basic idea of this apparatus seemed suitable for use in the study of the decarboxylation reaction, but the variation in carbon dioxide solubility in sulfuric acid solutions with small changes in pressure required changing to a constant pressure, variable volume system. We have, therefore, made the appropriate changes in design and constructed a gasometric apparatus which produces a continuous record of volume increase as a function of time with pressure held constant.

The kinetic apparatus was set up as shown in Figure 1 with the reaction vessel immersed in a thermostatted oil bath and fitted with a gas condenser leading to an insulated gas manifold. Attached to the manifold are a U-tube barostat open on one end to the atmosphere and a collection buret containing mercury which is connected to a motor

driven syringe. In operation, evolution of carbon dioxide caused the mercury in the open end of the barostat to make contact with an electrode, activating the motor driven syringe which then removed a volume of mercury from the collection buret equal to the volume of gas evolved. Increasing the system volume caused the electrical contact in the barostat to be broken, stopping the motor driven syringe. The worm drive moving the syringe plunger was attached directly to a 10-turn helical potentiometer. By means of a variable voltage divider network (3) a signal was produced which was recorded on a 1 mV chart recorder. As constructed, the apparatus was capable of measuring gas volumes up to 7 ml.

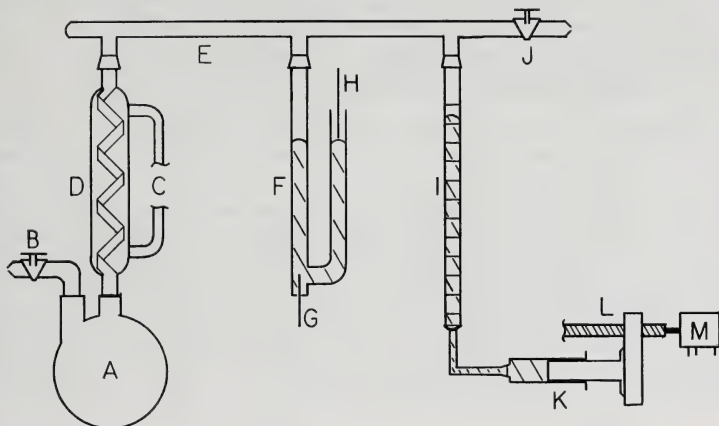


FIGURE 1. Schematic diagram of the gasometric apparatus. A, 250 ml, 2-necked reaction flask immersed in an oil bath; B & J stopcocks, C, water bath circulating coolant to gas condenser D; E, gas manifold insulated with glass wool and aluminum foil; F, barostat with mercury; G, platinum electrode; H, stainless steel electrode; I, gas collection buret containing mercury; K, motor-driven syringe; L, worm drive; M, 10-turn helipot.

Difficulties were experienced with the barostat at the mercury surface where contact was made and broken. Not until a stainless steel hypodermic needle was used as the electrode would the mercury surface remain smooth and liquid. The needle was positioned as close to the surface as possible to keep pressure variations at an absolute minimum.

The system was checked for accuracy and the output was calibrated by adding measured volumes of concentrated sulfuric acid to the closed system through the second neck of the reaction vessel. The temperature of the reaction vessel and of the circulating water which cooled the gas condenser were close to the usual reaction conditions. The measured additions of sulfuric acid equalled the volumes of mercury removed from the collection buret and produced on the recorder a linear response with less than $\pm 1\%$ error.

A typical run began with adjustment of the constant temperature baths; the oil bath was set at $80.0 \pm 0.1^\circ\text{C}$ and the water bath which was the source of the water circulated to the gas condenser was set at $25.0 \pm 0.1^\circ\text{C}$. Into the reaction vessel was placed 100 ml of 86.3%

sulfuric acid from a volumetric buret. This was stirred at a constant rate by means of a Teflon-covered stirring bar and a magnetic stirrer placed under the oil bath. Vigorous stirring is necessary to achieve good results. Then sulfuric acid-dried carbon dioxide was bubbled through the sulfuric acid reaction medium and the whole system was flushed with carbon dioxide for 10 min. The acid in the reaction vessel absorbed more than the equilibrium amount of carbon dioxide and after the gas tube had been removed and the system closed, outgassing would occur, sometimes up to 36 hours. This was allowed to proceed until the recorder showed no further evolution of carbon dioxide for at least 30 min, at which time it was assumed that the carbon dioxide and sulfuric acid mixture had reached equilibrium. The manifold stopcock was then opened, the collection buret was refilled with mercury, and the recorder was zeroed making the apparatus ready for the addition of the acid to be decarboxylated.

In test runs, mesitoic acid (sample size ~ 40 mg) was weighed in a platinum boat and stored under vacuum until it was transferred, boat and acid sample, to the reaction vessel through the side neck. The removable stopcock was then quickly replaced, the stopcock closed and gas evolution was recorded automatically. Recorder response was read at 1-min intervals and by means of a computer program was converted to moles of carbon dioxide evolved at STP and then to concentrations of mesitoic acid as a function of time. Figure 2 shows a least squares computer plot indicating good pseudo first order kinetics up to 86% completion of reaction.

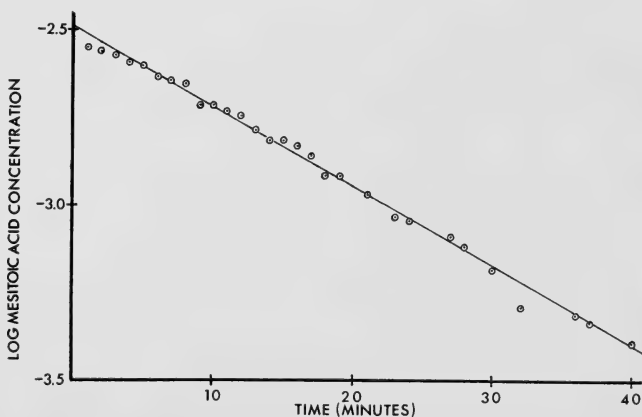


FIGURE 2. Typical computer plot showing pseudo first order kinetics in the decarboxylation of mesitoic acid. In this run, 48.1 mg of mesitoic acid was dissolved in 100 ml of 86.3% sulfuric acid. Reaction conditions: pressure—739.0 mm Hg, oil bath temperature—79.9°C, water bath temperature—25.1°C. Pseudo first order rate constant was $0.88 \times 10^{-3} \text{ sec}^{-1}$ with a standard deviation of $\pm 0.02 \times 10^{-3} \text{ sec}^{-1}$. The reaction had proceeded 86% of the way to completion after 40 min.

Nine independent determinations of the rate constant for the decarboxylation of mesitoic acid gave an average value of $k = 1.2 \times 10^{-3}$

sec^{-1} with a standard deviation of $\pm 0.3 \times 10^{-3} \text{ sec}^{-1}$. Earlier, Schubert (1) had reported a value for the pseudo first order rate constant for this decarboxylation reaction of $4.85 \times 10^{-3} \text{ sec}^{-1}$. Work in our laboratory (G. R. Bakker and L. E. Overman, unpublished data) had yielded a $k = 3.0 \times 10^{-4} \text{ sec}^{-1}$ at a reaction temperature of 60°C . Because reaction conditions in these studies were not identical with what we used, and the handling of data was also different, we cannot yet judge if the automatic gasometric apparatus we have devised is without systematic error. Fit of data points to the line over the extent of reaction as we have followed it indicate, however, that random errors are minimal.

Acknowledgements

The authors wish to thank the National Science Foundation and the E. I. du Pont de Nemours & Company for funding this research.

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ECOLOGY

Chairman: MARION T. JACKSON, Department of Life Sciences,
Indiana State University, Terre Haute, Indiana 47809

ROBERT O. PETTY, Department of Biology,
Wabash College, Crawfordsville, Indiana 47933,
was elected Chairman for 1974

ABSTRACTS

Analysis of Possible Successional Trends within the Tree Stratum in Old-growth Beech-maple Dominated Forests.¹ M. T. JACKSON, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—Twenty-one old-growth forest stands located in Indiana, Ohio and Michigan were sampled by taking 40, 1/40-hectare rectangular plots in each stand. In addition to the usual species attributes of density, frequency, basal area and importance values, the species were grouped into five moisture adaptation categories which range from xerophytic to hydrophytic. Analysis of changes in collective importance values by species-moisture category for canopy trees (>12 inches diameter breast height) *versus* sub-canopy trees (4-12 inches dbh) revealed that species shifts are occurring in several stands. Eight stands (Heuston, Toumey, Manlove, Officer, Hoot, Meltzer, Ogden and Haven Hill Woods) showed negligible changes. Six stands (Allee, Cox, Weaver, Logansport, Russ and Pine Hills Woods) appear to be increasing in wet mesic and mesic species, with corresponding declines in dry mesic and xeric trees. Seven stands (Warren, Bendix, Price Memorial, Versailles, Timberlane, Kado-Lato and Big Walnut Woods) exhibited an opposite trend with increasing values for dry mesic and xeric species, with corresponding declines in wet mesic and mesic species.

Greater importance values were recorded for American beech (*Fagus grandifolia* Ehrh.) than for sugar maple (*Acer saccharum* Marsh.) in the canopy stratum in 17 of the 21 stands. The four stands (Kado-Lato, Toumey, Price Memorial and Allee) where sugar maple had the greatest importance values were likely all used as maple sugar camps in the past, thus selection for sugar maple probably occurred. Conversely, sugar maple had higher importance values in the sub-canopy stratum than did American beech in 20 of 21 stands (Timberlane in Ohio, being the lone exception). These shifts in importance from canopy to sub-canopy strata are not proof that sugar maple is replacing beech as the stands mature. Differential survival rates between the two species maintain high levels of beech domination in old-growth stands. In fact, beech in the canopy stratum exceeded 35 per cent importance value in 15 of the 21 stands and exceeded 50 per cent importance value in four stands.

¹ A research grant from the Indiana Academy of Science for field expenses is gratefully acknowledged.

The Groundlayer of the Beech-Maple Association: A Community Structure Analysis.¹ JAMES B. LEVENSON,² Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—The groundlayer stratum was sampled by 40, 1/4000-hectare rectangular plots in each of 21 old-growth beech-maple forests in Indiana, Ohio, and Michigan during the summer of 1972. Density, frequency, abundance, constancy, commonness, importance value, and species association were compiled for all vascular plants less than 0.5 m tall within each stand and for the overall association. The groundlayer was a constantly varying assemblage containing a total of 174 species for all stands. Sugar maple (*Acer saccharum* Marsh.) and woodbine (*Parthenocissus quinquefolia* (L.) Blanch.) were dominant within the overall association, but were influenced by the inclusion and deletion of subordinate species among the 21 individual stands.

A community ordination of the 21 stands was constructed. The ordination was linear and controlled by the degree of domination by sugar maple and woodbine. A general inverse relationship between those two species suggested control by available light. Actual placement of each stand along the line was largely determined by a parallel moisture gradient.

A New Method for Extracting Tree Roots from Soil. BYRON HOLLETT,³ Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—A new method was developed to extract tree root material from soil samples (each sample was 2.5 centimeters in diameter by 7.5 to 15.0 centimeters long) the length depending on the depth from which the sample was taken. Also, specimens were taken from the root systems of tree seedlings which had been extracted.

Fiberglass screen cylinders (each 2.5 centimeters in diameter by 15.0 centimeters long with one end screened over) were securely fitted into 250 milliliter Ehrlenmeyer flasks. Each screen cylinder, containing a soil sample, was placed in a flask half filled with an aqueous solution of trisodium phosphate (trade name, Calgonite) which acts as a soil dispersing agent. The flasks were shaken at a low to moderate speed on an electric shaker for approximately 24 hours. The cylinders were then removed and washed under tap water to remove any remaining soil particles from the root material.

Root specimens were obtained from the tree seedlings by submerging the entire root system in a warm aqueous solution of Calgonite for 15-20 minutes, meanwhile agitating the trees by hand. The root systems were then washed under tap water to remove any remaining soil particles. Root sections were then cut with a scalpel.

These methods efficiently provided relatively soil-free root specimens from both individual samples and entire root masses.

¹ A research grant from the Indiana Academy of Science for field expenses is gratefully acknowledged.

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Site Preferences and Growth Responses of Kentucky Coffeetree, *Gymnocladus dioicus* (L.) K. Koch, Near the Center of its Range. MANSON LESLIE MCCLAIN,¹ Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—Vegetation associates, growth data, and soil samples were obtained within 0.1-acre circular plots centered around coffeetrees at 141 sites located in and around Vigo County, Indiana. Attributes tables were constructed and the soils were analyzed for pH, texture, and concentration of potassium, calcium, and magnesium.

Hackberry was the most prominent associated species followed by black walnut, American elm, and sugar maple. The coffeetree occurred on slope, terrace, upland, floodplain, and depressional topography. The coffeetree exhibited a preference for the lighter textured soils and was distributed bimodally with respect to pH, with occurrences generally around pH 6.0 and 8.0. Nutrient concentrations were higher in the topsoil than in the subsoil.

The coffeetree reproduces both sexually and vegetatively (by root suckers). The latter occurs more frequently and with greater growth rates especially in the more disturbed situations. Running water is probably the most effective dispersal mechanism followed by wind and human activity.

Bacterial and Chemical Analyses of Cardinal Creek Flowing through Ball State University, from May to December, 1972. PATRICIA A. EDDY, Department of Biology, Ball State University, Muncie, Indiana 47306.—Detailed bacterial and chemical studies were conducted on Cardinal Creek, flowing through the Ball State University campus from May to December, 1972. Samples were collected from drain pipes flowing into the stream and also from the center of the stream between drain pipes.

Results indicate that human waste materials are entering Cardinal Creek at the sampling site located behind the Ball State trailer courts. Ratios of fecal coliforms to fecal streptococci at this site were above 4.0 in 44% of the samples, thus indicating human waste contamination.

The presence of pathogens is another clue to the quality of surface water. *Salmonella* and *Shigella* are associated with gastrointestinal diseases that may be spread by ingestion of water contaminated with these bacteria. Both *Salmonella* and *Shigella* were isolated on several occasions from the drain pipe behind the trailer courts. *Salmonella paratyphi* (found on December 28) is evidence that human wastes are entering the stream.

Chemical data, collected on December 28, indicate a heavy load of organic matter is entering Cardinal Creek at the Ball State trailer court drain pipe. Of all the sites sampled on this date, the highest values for nitrogen and phosphorus and the lowest values for oxygen were found at the trailer court location. Measures should be taken to correct the situation.

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The Limitation of Oxygen Demand Tests for Water Pollution Control.

ROBERT H. L. HOWE, Eli Lilly and Company Tippecanoe Laboratories, Lafayette, Indiana 47902.—The limitation of biochemical oxygen demand, dichromate chemical oxygen demand and other oxygen-demand tests for water pollution control were discussed. Suggestions for improvement were presented.

Effect of Diquat upon the Root and Mycorrhiza System of *Liriodendron*

tulipifera L. JAMES M. SPROAT, Department of Biology, Ball State University, Muncie, Indiana 47306.—The effect of an herbicide (Diquat) upon the root and mycorrhiza system of the tuliptree (*Liriodendron tulipifera* L.) was determined. The herbicide was applied under normal field conditions and concentrations by spraying the tuliptree foliage. The trees were as similar in size, age, location and soil conditions as field conditions permitted. The aerial portions of the trees were removed at pre-determined time periods to prevent any further translocation. The root systems were then removed and analyzed for herbicide content. The herbicide concentration within the root system was determined by subjecting root (and mycorrhiza) samples (taken at three time intervals) to extraction and gas chromatography analysis.

Assessment of Characteristics of Strip-mined Areas of Indiana.

ROGER M. HOFFER,¹ L. A. BARTOLUCCI,² and J. S. BERKEBILE,² Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47906.—Due to pending legislation in Congress dealing with strip-mining procedures, detailed information is needed concerning the areal extent and condition of lands affected by strip-mining. Further information is required for a Department of Interior study dealing with assessment of the extent and quality of surface waters in strip-mined areas for fisheries potential. Small scale color infrared imagery (1:120,000) was used to estimate the areas of water bodies located in strip-mined areas of Indiana and to correlate spectral characteristics of the water with various aspects of water quality. The need for additional information prompted a computer-aided classification of multispectral scanner data gathered by aircraft over strip-mined land in Greene, Sullivan, Knox, and Daviess Counties. The correlation of spectral classes of water with pH levels was attempted. Acreage estimates of surface water, agricultural, and forest covers have been made. The results suggest a potential method for rapidly assessing many qualitative and quantitative characteristics of strip-mined land.

NOTE

An Ecological Analysis of the Shrub Stratum in the Beech-Maple Forest Type.³ HENRY M. DONSELMAN,⁴ Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—The tree, shrub, and

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³ A research argnt from the Indiana Academy of Science for field expenses is gratefully acknowledged.

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ground layer were sampled by 40, 1/400-hectare rectangular plots in each of 21 old-growth beech-maple forests in Indiana, Ohio, and Michigan during the summer of 1972. Only stands in which beech and hard maple comprised a total of at least 50 per cent of the canopy stratum were selected. Sites with a recent history of grazing, burning, or timbering were not used.

Density, frequency, distribution, and species associations were compiled for each species in each stand and for the entire study area. A three-dimensional ordination was constructed, based on the importance values of the species (1).

The following conclusions relate to the shrub layer of the Beech-Maple Association:

- 1) A single plant community was not present in the Beech-Maple Association, rather, several communities approach a continuum which depends on climatic, edaphic, and geographic factors.
- 2) Sugar maple (*Acer saccharum* Marsh.) reproduction and spicebush (*Lindera benzoin* L. Blume.) were the most important component species of the shrub layer.
- 3) The importance of American beech (*Fagus grandifolia* Ehrh.) was attributed to the even distribution and high frequency of the species in each stand and throughout the Association.
- 4) The importance of sugar maple and beech in the shrub stratum was generally higher in northern stands and lower in southern stands, substantiating the theory that the Beech-Maple Association is best developed on youthful topography.
- 5) Eleven combinations of 8 woody species were found to dominate the 21 stands.
- 6) Only two species, sugar maple and American beech, were sampled in all 21 stands.
- 7) Sugar maple, due to its high frequency, significantly associated with the most species on both the intrastand and interstand level.
- 8) Beech and maple associated positively in 20 of the 21 stands.
- 9) Unusually high numbers of negative species associations were found for bitternut hickory (*Carya cordiformis* (Wang.) K. Koch.), spicebush, pawpaw (*Asimina triloba* (L.) Dunal.) and hop-hornbean (*Ostrya virginiana* (Mill.) K. Koch.) on the interstand level.
- 10) The number of woody species in the shrub stratum was influenced by the amount of past disturbance and number of microhabitats in a stand.
- 11) Work with the ground layer (2) and the tree stratum (Jackson, unpubl. data) indicate that the ground layer is largely controlled by micro-environments, the shrub layer by both the micro-environment and regional environment, and the tree stratum by the regional environment.
- 12) Stands in which the regional climate is modified have a mixing of northern or southern species with the species common in that area.

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The Phenological Response of Five Perennial Plant Species at Five Locations in Indiana to Climatic Variations 1966-1972¹

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Abstract

The appearance of first leaf (phenophase) of five perennial species at five locations in Indiana was reported. Location of planting varied from Johnson (south) to Wanatah (north) and from Johnson (west) to Farmland (east). All sites had different soil type, elevation and climate pattern.

The appearance of the first leaf of the species observed varied from 24 to 29 days from south to north. The extremes in days to appearance of first leaf among species and years varied from 20 days in big bluestem (*Andropogon gerardi* L.), the most uniform to leaf, to 29 days in fall aster (*Aster azurea* L.). Considering all species, Dubois was the most consistent location having the least variation (18 days) and Johnson and Wanatah the greatest (29 days), to appearance of first leaf.

The 3-4 week earlier start in growth in the south strongly supports culturing earlier planting of cool season agronomic and horticulture crops. This indicates that double cropping, the practice of following a first crop of wheat, barley or winter oats with a second crop of soybeans or sorghum, should be encouraged. This would be a more preferable alternative than increasing the acreage of highly erosive land which is presently under permanent cover. Such areas have been in a concerted program of erosion and flood control for the past 30 years, and cultivation of these areas not only may induce flooding and severe erosion but in some instances may disrupt current domestic water supplies.

Introduction

The seasonal response of organisms to the total environment varies from species to species and year to year. Certain specific events, which can be observed by date each year with a degree of precision such as budding, flowering, fruiting, etc., are referred to as stages of development or phenophases. Observation of such events, as they vary from year to year in plants, were probably noted before man domesticated economic animals and cultivated economic species from the plant kingdom. Isolation, selection, culturing and natural genetic manipulation of these species over time has given man his present food supply.

Plants native or adapted to a range of climatic belts can be useful in interpreting seasonal phenophase variations. This paper is an introduction to the observations on phenophase responses in the appearance of the first leaf of both economic and native plant species in Indiana.

Review of Literature

One of the earliest efforts to organize a network system for observing plants as they developed from season to season was reported

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by Linneaus in "Philosophea Botanica" in 1751 (7). He described a network of 18 stations in Sweden. Early attempts (such as he described) were hampered and limited by lack of interest, communication and transportation. Those systems initiated were usually intensive individual efforts made by devoted naturalists (5, 9, 10) and confined to limited areas. In 1905, the U.S. Department of Agriculture (then a part of the U.S. Weather Bureau) attempted a rather elaborate phenology program, but terminated it after four years (13).

Since 1945, advancements in communication, transportation and a change in research techniques have fostered renewed interest in phenological research in both Europe and the United States. Studies by individual scientists have grown into cooperative network endeavors. Caprio's 1,300 station network in the western United States and Schnelling's studies in Central Europe are examples of the new approach which employs the organization, communication, and cooperation of many people for completing observations over large areas (2, 3, 11).

Successful application of the results of phenological studies in making economic decisions has also encouraged continued effort in collecting data on seasonal variation in perennial plants. Coaker and Wright in England and Fulton in North Carolina related certain phenophases of plants to the appearance of the cabbage maggot (*Hylemyia brassicae* Bouché) (4, 6). In Indiana the heading of orchardgrass (*Dactylis glomerata* L.) can be closely associated with the appearance of the adult European corn borer (*Ostrinia nubilalis* Hubner) while ripening of the fruits of bush honeysuckle (*Lonicera tatarica* L.) appears to correlate with the maturation of the current varieties of soft red winter wheat. The evolution of appearance of first leaf and full bloom of Persian lilac "Red Rothamogensis" (*Syringia persian* L.) in Eastern and Central North America during 1960-72, which included phenological data from over 1,700 locations, was reported by Hopp and Blair (8).

The purpose of this study was to describe the influence of year-to-year climatic variations on initiation of the first leaf of five species at five different locations in Indiana (from 1966-72). The organization of the Indiana phenology garden network was published previously (1).

Materials and Methods

In 1960, the Indiana Phenology garden system began as a part of a regional project with four locations and one species. In 1964, eight additional locations and 11 new species were introduced. Perennial plants were selected so that two species would flower each month throughout the growing season. The original study was confined to observation on Persian lilac, 'Red Rothmagensis'.

The gardens involved in this paper and their locations are listed in Table 1. Species reported herein represent those which provided the most complete information to date. They include the following:

Persian lilac (<i>Syringa persian</i> L. "Rothomagensis")	— flowering early spring
Spirea (<i>Spirea spec</i> L.)	— spring
Orchardgrass (<i>Dactylis glomerata</i> L.)	— spring
Big bluestem (<i>Andropogon gerardi</i> L.)	— summer
Aster (<i>Aster azurens</i> L.)	— late summer

All species except lilac were established from an original cutting or clone, started in the greenhouse, transplanted to a nursery, then later transferred to the field in the fall of 1964. Lilac plants were purchased from a commercial nursery in Nebraska.

TABLE 1. Location of the five gardens reported in study and yearly climatic variation.

	Johnson	Dubois	Farmland	Columbia City	Wanatah
County-----	Gibson	Dubois	Randolph	Whitley	LaPorte
Latitude -----	38°16'N	38°27'N	40°08'W	41°09'W	41°31'N
Longitude -----	87°45'N	86°42'W	85°12'W	85°25'W	87°02'W
Elevation -----	131 m	210 m	294 m	269 m	246 m
Mean Temp. -----	14°C	12°C	12.5°C	10°C	9°C
Max. Temp. -----	43°C	40°C	41°C	39°C	40°C
Min. Temp. -----	-28°C	-29°C	-27°C	-27°C	-29°C
Mean Precip. -----	107.0 cm	107.0 cm	100.2 cm	94.3 cm	93.9 cm
Soil Type -----	Princeton Fine Sand	Tilsit Silt Loam	Blount Silt Loam	St Clair Silt Loam	Trace Sandy Loam

All plantings were located near official weather stations. Official Weather Observers, with the aid of a specially prepared manual of color photos of all phenophases, reported the dates of all observed phenophase events each year.



FIGURE 1. Planting arrangement of a typical phenology garden.

An established phenology garden is shown in Figure 1. Observations of the appearance of the first leaf by years, species and locations are summarized in Table 2.

TABLE 2. *Appearance of the first leaf on five species at five locations in Indiana 1966-72.*

Locations	Persian Lilac				Spirea				Orchardgrass				Big bluestem				Aster				Mean differences Among Species			
	M	E	L	D	M	E	L	D	M	E	L	D	M	E	L	D	M	E	L	D				
Johnson	3/19	3/12	4/10	(29)	4/2	3/18	4/12	(25)	3/22	3/10	4/2	(23)	4/13	4/1	4/20	(19)	3/29	3/11	4/8	(28)	[29]			
Dubois	3/18	3/13	3/25	(12*)	4/26	3/15	4/11	(27)	3/20	3/13	3/27	(14)	4/8	3/25	4/20	(26)	4/14	4/7	4/20	(13)	[18]*			
Farmland	4/8	3/23	4/21	(29)	4/15	4/6	4/21	(15)	3/30	3/18	4/14	(27)	5/3	4/25	5/7	(13)	4/13	3/21	5/1	(41**)	[25]			
Columbia City	4/9	3/27	4/23	(27)	4/16	4/4	4/23	(19)	4/2	3/11	4/15	(35)	5/2	4/21	5/8	(17)	4/10	4/4	4/17	(13)	[22]			
Wanatah	4/12	3/25	4/30	(36)	4/18	4/6	4/28	(22)	4/28	4/15	5/11	(26)	5/7	4/10	5/14	(24)	4/26	4/8	5/13	(35)	[29]			
Range in appearance of first leaf South-North	→				→				→				→				→				→			
Mean days among locations in appearance of first leaf	24				24				24				29				29				28			
	(26)				(22)				(26)				*** (20)				(26)							

M - Mean date	E - Earliest date	L - Latest date	D - Range
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M - Mean date E - Earliest date L - Latest date D - Range

* Least difference in days to appearance of first leaf (among years)

** Greatest difference in days to appearance of first leaf (among years)

*** Most uniform in appearance of first leaf (among species)

Results

The location of the five stations reported in this paper vary from Johnson (south) to Wanatah (north) and from Johnson (west) to Farmland (east) with elevations varying from 131 to 294 m and soil types varying from sand to silt loam (Table 1). Southern locations average 54 more days of frost free growing conditions than in the north, and total precipitation increases about 13 cm from north to south. Drought stress is more frequently a problem at Johnson, however, than at Wanatah due to the additional growing days with only 13 cm added rainfall at this location.

Temperature extremes among the locations varied little over a 27-year period. However, temperature variation within given years results in considerable differences in timing of first leaf appearance. The average dates of appearance of the first leaf of each species at each location are presented in Table 2. Species which flower in early spring and summer tend to generate vegetative growth earlier than later flowering species. The first leaf on some species (*i.e.*, Persian lilac, Spirea) arises from secondary tissue generated the previous year, whereas the grasses and aster generate new leaf tissue from crown buds. The latter species might be expected to develop leaf tissue earlier as such growth may be more directly related to soil temperature which in spring is warmer than mean air temperature. Species with leaf tissue generating from buds in the soil also may have advantage in that diurnal soil temperature fluctuations are not as great as above-ground air temperatures, nor do water and nutrients have to be translocated as far to reach and activate growing regions (12). Since the point of origin of new leaf tissue differs among these species, no attempt has been made to relate a degree day or heat unit approach to this data as described by Lindsey and Newman (11). Evaluation of soil and air temperature to the appearance of first leaf and first bloom are in progress.

The extremes in average appearance of first leaves of the 1966-72 period for all species varied from 24-29 days among species from north to south (Table 2). This suggests that at Johnson, the season starts about 4 weeks earlier on the average than at Wanatah.

In considering the appearance of the first leaf among the five species, especially since they differ in growth habit, differences in air temperature in early spring among the various locations may have imposed limitations on growth. A summary of the mean temperature and precipitation values for March and April which correlate with this phenophase are shown in Table 3. The climatic conditions during this period obviously are critical to the timing of leafing.

March and April air temperatures averaged about 4°C warmer at Johnson than at Columbia City and Wanatah. The 4°C temperature difference over this 60-day period accounts for the early and rapid development of a given plant species located at the contrasting sites. More information is needed on the contribution of soil temperature to this phenophase. Precipitation was adequate at all locations during the beginning of growth.

TABLE 3. *Mean March and April air temperature and precipitation during 1966-72.*

Location	Temperature °C		Precipitation cm	
	March	April	March	April
Johnson -----	5.7	12.7	8.23	13.16
Dubois -----	5.0	12.4	7.62	12.67
Farmland -----	1.8	9.0	5.41	9.02
Columbia City -----	1.3	8.8	5.61	10.05
Wanatah -----	1.7	8.8	5.86	9.42
Mean of all locations -----	3.1	10.5	6.55	10.87
Range in mean temperature and precipitation -----	4.4	3.9	2.82	3.74

The dates of initiation of first leaf of these five species (although they all flower at a different period in the season and vary in growth form) give information regarding the response of genetically controlled specimens to variation in Indiana climate.

These data, in general, support Hopkin's Bioclimatic Law with regard to latitude. The elevation and longitude dimensions are too limiting to expect close correlation.

The variation (range) in first phenophase for each species is shown in Table 2. These data show that big bluestem has the fewest days (20) or least variation to appearance of first leaf over all locations. This may result from the residue from the previous year's growth offering protection from less diurnal soil temperature fluctuations. Other species were more prominently or totally exposed and have little protection from normal air temperature modifications, suggesting again that more stable environmental conditions in the soil contribute to a more uniform start of leaf bud growth.

The greatest variation in appearance of first leaf at a given location occurred in aster which has a similar growth habit to big bluestem, but leaves no stubble residue, with an exposure similar to bare soil. This occurred in Farmland, the highest in elevation and one of the coldest locations in the spring. Soils at this location are high in clay and also have poorer drainage than soils from the other four sites.

Among the five locations, Dubois on the average shows the least variation in appearance of the first leaf for the five plant species studied. Average variation in first leaf appearance was 18 days for Dubois as compared with 29 days for Johnson and Wanatah.

Additional data for this phenophase at these locations is needed before more detailed conclusions can be made. Evaluation of other phenophases may also contribute additional useful information for describing variations among locations over years.

Conclusions

Observations of the dates of appearance of the first leaf were made on five species at five different locations in Indiana on several soil types. It was found that: 1) variation in first leafing was 24-29 days (3-4 weeks) later in northern than in southern Indiana, due pri-

marily to temperature differences; and 2) large within-location variation in first leafing existed over the periods observed.

Practical application of this information indicates that cool season spring-planted crops and vegetables can be safely started in mid-March in southern Indiana, at least 3 weeks earlier than in northern Indiana.

Double cropping (the practice of following a winter small grain crop that matures in late June with a summer annual such as soybeans or sorghum) is well suited to the longer growing season of southern Indiana and should be encouraged to help overcome the present food and feed grain shortages. This cropping practice would be more effective than expanding production to less desirable acreages, many of which have been under a successful conservation program for more than 30 years.

The year to year within-location variation that occurred in this study would indicate that cool season perennials should have a better overall performance record than summer annual crops with higher temperature and water requirements.

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Microclimatic Measurements and Use of Artificial Shelter by Confined Cottontails¹

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Abstract

Five adult cottontails (*Sylvilagus floridanus mearnsii*) held in each of four 50 x 50-foot outdoor pens were located each day in their daytime resting places. They used five shelter types replicated in the pens. In two pens an artificial den system was used more than all other types together. For 1,298 total resting locations in all pens, 47 per cent were in the den systems alone, the remainder being in the other 4 shelter types. Adult females dominated all den chambers and reduced total incidence of den use by other individuals. Temperatures in the den chamber fluctuated less, were higher in winter and lower in summer than those in surface shelters and for true air temperature. Soil temperatures fluctuated less than those in the den chamber at corresponding depths. One rabbit warmed the immediate ambient temperature where it rested in the den but not that at 15 inches distant. Relative humidity in the den chamber increased, when a rabbit entered and rested there during the day, and dropped when the rabbit left at evening, a cycle diametrically opposed to that aboveground.

The cottontail rabbit is a primary small game species for a large number of people who use it for recreation and food. Its requirements for continued production are worth knowing especially as a basis for its management. Although cottontails may appear to thrive on an assortment of environmental conditions, some conditions are preferred over others at some times.

Cottontails capably use many kinds of natural and artificial shelter aboveground. Their use of natural burrows is also well-known. Trautman (*in* Trippensee, 10) noticed the holing-up behavior of cottontails when snow covered the ground and temperatures dropped below 20°F. He also observed that females tended to use holes more than males. Gerstell (3) related that of 878 rabbits taken by hunters on 3 consecutive days only 21% were females. It appeared that the majority of female rabbits were underground, whereas most of the male population remained in aboveground forms. Other studies (1, 6) show the relationship between the cottontail and woodchuck (*Marmota monax*) burrows. Woodchuck holes seem to be the most important form of underground cover used by cottontails. Allen (1) pointed out that, although rabbits appeared to be more abundant in areas dotted with woodchuck holes, the holes alone did not increase rabbit density.

From a study by Smith (8), whose main objective was to determine how weather changes influence cottontail behavior, we have temperature data related to the use of various shelters by cottontails. A part of that study was to correlate temperature (and in one case relative

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humidity) data with use of artificial shelters by confined rabbits, which is reported here.

Materials and Methods

Wild cottontail rabbits were kept in a 200 x 140-foot outdoor enclosure on the Purdue Wildlife Area located about 7 miles west of West Lafayette, Indiana. Ground predators were excluded by a 5-foot fence of 3-inch diamond-mesh wire overlain by 1-inch wire netting. Hardware cloth (0.5-inch mesh) was buried 12 inches below the surface and extended 12 inches above the surface at the base of the fence. A nylon net covered the top of the enclosure to protect against hawks and owls. The main enclosure was subdivided into 50-foot-square pens, and four used in this study were each stocked with two male and three female adult cottontails.

About 90% of the vegetation within the enclosure was Kentucky bluegrass (*Poa pratensis*) and bird's-foot trefoil (*Lotus corniculatus*). The remaining vegetation was made up of native species. Frequent mowing kept the vegetation uniformly short for good observation. The rabbits grazed extensively on the broad-leaved plants, with bird's-foot trefoil being the least preferred species. Purina Rabbit Chow was always available, and corn and apples were fed intermittently throughout the year. Water and artificial shelter were provided in each pen.

Observations were made from a 10 x 6 x 6-foot hide atop a 12-foot tower adjacent to the enclosure. For individual identification, the rabbits were marked in each ear with a colored, plastic tag (Rototag, Nasco, Ft. Atkinson, Wis.) visible up to 100 feet. The tags appeared to have no effect on the cottontails' behavior. In addition to the Rototags, 16 rabbits were marked with a distinct fur dye pattern.

Five artificial shelters were provided in each pen. Four shelters were placed on the surface and the other, a wooden construction, was buried in the ground. The underground den was a 15 x 15 x 36-inch exterior plywood box buried 30 inches into the ground. Six inches of the box extended above the surface. Wood tunnels, 4 x 4-inch x 9-foot, slanted from opposite sides at the base of the box to the surface. Two lids to the box made the structure dark and watertight. The floor of the tunnels and the den chamber were open to the soil. The box rested on 12 inches of gravel to prevent flooding.

The surface shelters were evenly spaced around the underground den. One type was created with a piece of 3 x 4-foot snow-fence bent into an arch and thatched with straw. A feeding shelter, 10 inches high, 2 feet wide, and 5 feet long, was made of sheet metal bent into an arch and nailed to a wooden frame (Herald Demaree, Jr., pers. comm.). This shelter provided cover and protected the food from precipitation. Three wooden boxes, 4 x 4-inch x 3-foot, placed in the shape of a "Y", provided shelter for several rabbits at the same time. Open to earth at the bottom, these boxes were covered with a piece of plywood and thatched with straw during the winter. The fifth artificial shelter was made of three 6-inch x 3-foot concrete bell-end pipes arranged similarly to the three wooden boxes.

To determine the amount of use for each artificial shelter, a morning inventory of 20 cottontails was conducted intermittently from October 1971 to August 1972. After rabbit activity ceased, at approximately 1000 hours, an observer entered the pens and recorded the location of each animal on a detailed map. Each pen was divided into a grid of 16 blocks. Thus, each of the 20 rabbits could be recorded in one of 21 possible locations, including the five shelters.

Temperature and humidity within the underground chamber were measured at hourly intervals. In addition, temperature measurements were made 1) at two levels within the underground tunnels; and 2) at depths in the soil corresponding to the same depths measured in the burrow chamber and tunnels. Relative humidity measurements were made by suspending a Bendix hygrothermograph so that the bottom of the instrument was at a depth of about 20 inches inside the burrow chamber. The record from this instrument was compared with true air relative humidity, measured with a hygrothermograph housed in a standard shelter mounted 12 inches aboveground. (True air temperature and humidity are temperature and humidity measured in a standard instrument shelter.) Temperature readings were taken with a Honeywell multi-channelled millivolt recorder located in the observation tower. Thermocouple wire of Teflon-coated copper-constantin led from the recorder to points being monitored in the pens and the weather shelter house.

Results and Discussion

The rabbits used all artificial shelters, but favored some more than others. The underground structures were preferred for escape cover as well as for protection from the weather. The rabbits immediately accepted the artificial burrows and showed little fear of the new structures.

Use of Underground *versus* Aboveground Shelters

The den system frequently held three rabbits (one in the chamber and one in each tunnel) without aggressive behavior (Tables 2 and 3). Therefore, the den was limited in the number of animals it could shelter, in contrast to aboveground cover, consisting of four artificial structures and many hundred square feet of vegetation. Total percentage use for all pens shows that underground (chamber and tunnels) use (47%) was nearly equal to surface use (53%) (Table 1). Den use in Pens 1 and 3 was roughly twice that of all other available shelters. The rabbits also used the underground dens continuously in summer (Tables 2 and 3).

Previous studies showed the use of woodchuck burrows by cottontails and emphasized the importance of such shelter during cold winter weather (1, 3, 5). The possible use of natural ground holes by cottontails during summer was not mentioned. In this study, it is probable that much of the artificial burrow use by the confined rabbit population was a function of their confinement in high densities (87 rabbits per acre). We speculate that in the natural environment cottontails benefit from use of burrows in summer as well as winter.

TABLE 1. *Number of times and per cent of total times rabbits were found in each shelter type for period of 13 October 1971 to 6 March 1972.*

Rabbit	Sex	Observations	Underground				Surface			
			Chamber		Tunnels		Artificial (4 types)		Vegetation	
Pen 1										
P1	Fe	61	61%	37	28%	17	3%	2	8%	5
Y1	Fe	60	1%	1	8%	5	72%	44	18%	11
R1	M	61	16%	10	77%	47	0	0	7%	4
G1	M	61	1%	1	18%	11	20%	12	60%	36
W1	M	61	21%	13	77%	47	0	0	1%	1
Total obser.		304	20%	62	42%	127	19%	58	18%	56
Total % use per pen				63%				37%		
Pen 3										
P3	Fe	64	83%	53	17%	11	0	0	0	0
Y3	Fe	65	1%	1	63%	41	11%	7	25%	16
R3	M	67	1%	1	60%	40	15%	10	24%	16
G3	M	65	1%	1	91%	59	1%	1	6%	4
W3	M	67	0%	0	7%	5	34%	23	58%	39
Total obser.		328	17%	56	46%	156	13%	41	23%	75
Total % use per pen				65%				35%		
Pen 4										
P4	Fe	67	85%	57	9%	6	0	0	5%	3
Y4	Fe	67	0	0	10%	7	60%	40	30%	20
R4	M	67	0	0	0	0	36%	24	64%	43
G4	M	67	0	0	1%	1	43%	29	55%	37
W4	M	67	0	0	46%	31	37%	25	16%	11
Total obser.		335	17%	57	13%	45	35%	118	34%	114
Total % use per pen				31%				69%		
Pen 5										
P5	Fe	66	1%	1	38%	25	55%	36	6%	4
Y5	Fe	64	70%	45	25%	16	0	0	5%	3
R5	M	67	7%	1	1%	1	55%	37	42%	28
G5	M	67	0	0	13%	9	54%	36	33%	22
W5	M	67	0	0	15%	10	61%	41	24%	16
Total obser.		331	14%	47	18%	61	45%	150	22%	73
Total % use per pen				33%				67%		
Total % use for all pens				47%				53%		

Rabbit Behavior Relative to Den

Free-ranging female cottontails are more often found underground than males (3, 10). Female rabbits also appear to have a smaller home range than males (2, 4, 7). While we assumed that each of our rabbits used the entire 50-foot-square pen as its range, females clearly dominated the underground den chambers (Table 1). In a companion study, Smith and Frazer (unpublished data) substantiated the empirical observation that undisturbed rabbits habitually use a favorite lying-up spot.

TABLE 2. *Change in female dominance of den chamber in Pen 1.*

Date	North Tunnel	Chamber	South Tunnel
July 18		R1	G1
July 19	W1	G1	P1
July 20	Y1	G1, P1	R1
July 25	Y1, G1 ¹		P1, R1
July 26	R1	P1	Y1, G1
July 31	R1	P1	
Aug. 1	Y1	R1	P1
Aug. 2	W1	Y1	P1, R1
Aug. 3	G1, Y1	P1	R1
Aug. 4	P1	R1, Y1	
Aug. 7	R1	P1	W1, Y1
Aug. 8	R1	P1	
Aug. 10		Y1, P1	R1
Aug. 11	W1	Y1	P1, R1
Aug. 18	Y1, G1	P1	R1
Aug. 21	R1	P1, G1	Y1
Aug. 25	G1	Y1	P1, R1
Aug. 28		Y1, R1	P1
Aug. 30		Y1	G1, R1
Sept. 11	G1	Y1	R1

P1=Female; Y1=Female; R1=Male; G1=Male; W1=Male.

¹ Two code numbers indicate 2 rabbits spaced apart.

Marsden and Holler (6) discussed a rigid and fairly linear dominance hierarchy among confined male cottontails. They also reported a clearly established female hierarchy, but emphasized the lack of a rigid and linear dominance relationship as compared to the males. In this study, with respect to the dens, dominant females repelled all

TABLE 3. *Stable female dominance of den chamber in Pen 3.*

Date	North Tunnel	Chamber	South Tunnel
July 18	Y3	P3	
July 19	Y3	P3	G3
July 20	Y3	P3	G3
July 25		P3	G3
July 26	Y3	P3	G3
July 31	W3, G3	P3	Y3
Aug. 1		P3	G3
Aug. 2	W3	P3	G3, Y3
Aug. 3	Y3	P3	G3
Aug. 4	Y3	P3	G3
Aug. 7		P3	
Aug. 8		P3	
Aug. 10	Y3, G3	P3	
Aug. 11		P3	
Aug. 18	W3	P3	Y3
Aug. 21	Y3, G3	P3	
Aug. 25		P3	W3, Y3
Aug. 28	Y3, W3	P3	G3
Aug. 30	Y3	P3	G3
Sept. 11	Y3	P3	G3

P3=Female; Y3=Female; G3=Male; W3=Male.

males as well as subordinate females. Quantities of fur and patches of blood in dens and tunnels occupied by females suggested that the dominant females aggressively defended the chambers, but not the whole system (see above).

Females P1, P3, P4, and Y5 dominated the den chambers in their pens during the winter of 1971-72 (Table 1). Observations made during the summer of 1972 also showed that dominance of females using three of the four chambers remained the same. In Pen 1 the dominance hierarchy associated with the burrow was in a state of turmoil as compared to a stable hierarchy in Pen 3 (Tables 2 and 3). At the time the summer observations were made, the dominant female P1 was almost 3 years old. Perhaps aging decreased her dominance. On 3 September, near the end of the summer observations, P1 was found dead without evident wounds. We immediately replaced her with another female. When the study was terminated on 1 January 1973, female Y1, the original subordinate animal, dominated the chamber.

Microclimatology of Artificial Shelters

Temperatures in the burrows and in each artificial shelter were measured and tabulated by Smith from June 1971 to January 1973 (8). His data show the stability of the burrow microclimate on typical summer and winter days. Although there was marked fluctuation in the true air temperature cycles in both seasons, the temperature within the den chamber remained nearly unchanged (Tables 4 and 5). The temperatures within the four surface shelters closely followed that of true air temperature (8). The value of the surface shelters to cottontails probably lies in their ability to protect from wind, precipitation, and direct sunlight, or merely to offer a place to hide. In winter, a strong wind with high relative humidity decreases the effective temperature acting on the animal. In summer, calm conditions with direct sunlight would increase effective temperature on the rabbit. Cottontails no doubt favor those resting places that protect them from stress and help in maintenance of their homiothermic status.

Burrow Microclimate. To make comparisons between true air, burrow, and soil temperatures, temperatures were recorded at three points in the den chamber, two points in the tunnels, and at soil depths corresponding to the points in the chamber (Tables 4 and 5). Table 4 shows the data for a typical fall day, and Table 5 for a winter day.

On 31 October true air temperature fluctuated 30°F while burrow temperatures at 18 inches and 30 inches fluctuated only 7°F and 4°F, respectively. Fluctuations at the lowest point of the tunnel, *i.e.*, 30 inches below the surface, and halfway between there and the surface, were 7°F and 6°F, respectively. Temperature fluctuation at 1-inch soil depth was a spread of 22°F, about one-quarter less than that for true air temperature.

At 18-inch and 30-inch soil depths, the variations were 2 and 1°F, respectively. Although the temperatures in the burrow at 30 inches are similar to those in the soil at the same depth, we attribute any

difference to the movement of cold air downward via the double lids and tunnels into the chamber. This implies that a natural den chamber situated above the lowest level of entrance tunnels would aid an animal occupant in heat conservation.

TABLE 4. *Temperature cycles (°F) for a typical fall day on 31 October 1971.*

Time	True Air 1 ft. Above Ground	Artificial Burrow System					Depth of Sensor in Soil		
		Chamber			Tunnel				
		Ground Level	18 in.	30 in.	Lowest				
					Point	Middle	1 in.	18 in.	30 in.
0800	46	57	57	60	60	60	51	60	60
0900	49	59	59	61	60	60	54	60	60
1000	54	60	61	61	61	60	55	60	60
1100	57	60	60	61	61	61	59	60	60
1200	60	61	61	61	61	61	63	61	61
1300	61	62	62	62	62	61	64	61	61
1400	61	62	62	62	61	61	64	61	61
1500	61	62	62	62	61	61	61	60	60
1600	59	62	61	62	61	60	57	60	60
1700	53	62	62	61	61	60	55	60	60
1800	43	60	61	61	60	59	52	60	60
1900	39	58	59	60	59	59	49	60	60
2000	37	57	59	60	58	58	48	60	60
2100	36	56	58	60	57	57	47	60	60
2200	34	55	57	59	57	57	45	60	60
2300	33	54	56	58	57	57	44	60	60
2400	34	52	56	58	56	56	44	60	60
0100	31	51	56	58	56	56	43	60	60
0200	32	51	55	58	55	55	42	60	60
0300	35	50	56	59	56	56	42	60	61
0400	34	50	55	58	55	55	42	60	60
0500	33	49	55	58	55	55	42	60	60
0600	37	49	55	58	56	56	43	60	60
0700	42	50	56	58	57	57	44	59	60

The burrow system showed more temperature variation than the soil, where temperatures were very stable at 18-inch and 30-inch depths. The soil did not cool as much as the burrow chamber. Evidently the wood construction of the den system acts as a channel for air movement while possibly preventing heat transfer from warmer soil to the cavity.

A true air low reading of -14°F was recorded 14 January 1972, while the burrow temperature at the same hour was 44°F warmer. Temperature fluctuations of 27°F true air, 12°F at the bottom of the chamber and 2-3°F in the tunnel, clearly show the heat conservation of the den system.

Modification of Burrow Microclimate. Sunquist (9) reported that in winter the temperature of an occupied skunk den was 8°F higher than in an unoccupied den. In our study, one cottontail had little effect on den temperature. Figure 1 shows a 30-hour temperature cycle recorded in opposite corners at the floor of one chamber. From about

0800 to 1700 hours, the temperature in the southwest corner ranged from 2° to 6°F warmer than the opposite corner. Female P3 habitually rested in the southwest corner of the chamber, about one-half inch from one temperature sensor. At night, when P3 was active aboveground, the two corner temperatures coincided. Although the rabbit warmed the air of the chamber immediately around it, no increase in temperature could be detected 12-15 inches away.

For the period 29 November-6 December 1971, two hygrothermographs simultaneously recorded relative humidity within the den chamber and 1 foot aboveground. The records show that den humidity was influenced by presence or absence of a rabbit (8). On days when precipitation or heavy cloud cover occurred, both den and surface humidities reached and stayed at 100% around the clock. On days without precipitation and with sunshine, relative humidity aboveground decreased to a low of 40% at noon. At the same time, den humidity, which had dropped to 80% during the night, increased to 100%, and started to fall off again about 1700 hours. During three cycles of "drying" days, relative humidity curves for the two locations were more or less completely out of phase.

One explanation is that the artificial den's relative humidity cycle was disturbed by a rabbit known to be or not to be in the chamber.

TABLE 5. *Temperature cycles (°F) for a typical winter day on 14 January 1972.*

Time	True Air 1 ft. Above Ground	Artificial Burrow System					Depth of Sensor in Soil		
		Chamber			Tunnel				
		Ground Level	18 in.	30 in.	Lowest Point	Middle	1 in.	18 in.	30 in.
0800	—3	--	33	35	34	33	34	39	43
0900	8	--	35	37	35	33	34	39	43
1000	12	--	35	38	35	34	34	39	43
1100	13	--	35	39	35	34	34	39	43
1200	12	--	35	39	35	34	34	39	43
1300	11	--	35	39	35	34	34	39	43
1400	8	--	36	39	36	34	34	39	43
1500	6	--	37	39	36	34	34	39	43
1600	4	--	36	40	36	34	34	39	43
1700	1	--	35	40	35	34	34	39	43
1800	—2	--	34	35	34	33	34	39	43
1900	—3	--	34	34	34	33	34	39	43
2000	—4	--	33	34	34	33	34	39	43
2100	—5	--	33	33	33	33	34	39	43
2200	—7	--	32	31	33	32	34	39	43
2300	—8	--	30	30	33	32	34	39	43
2400	—11	--	30	30	33	32	34	39	43
0100	—11	--	30	30	33	32	34	39	43
0200	—11	--	30	29	33	32	34	39	43
0300	—11	--	30	29	33	32	34	39	43
0400	—10	--	30	29	33	32	34	39	43
0500	—10	--	30	29	33	32	34	39	43
0600	—12	--	30	28	33	32	34	39	43
0700	—14	--	30	30	33	32	34	39	43

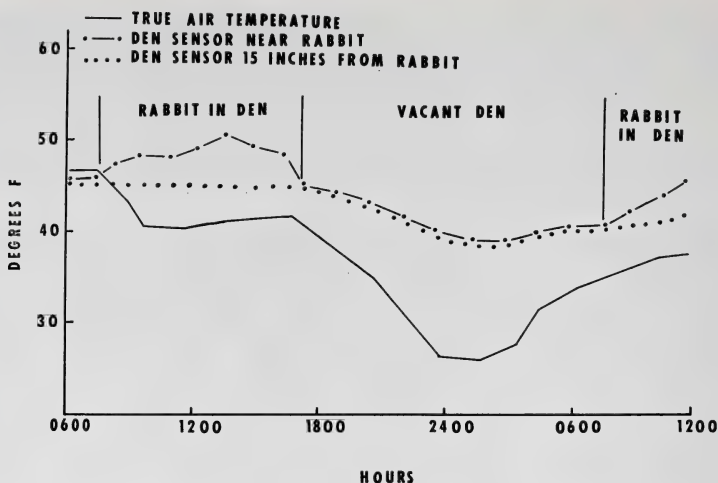


FIGURE 1. Temperature cycle of 30 hours 24-25 December 1971 showing influence of rabbit on temperature of den chamber.

Each day at about 1700 hours, when female P3 came aboveground, den humidity dropped. The next morning, when P3 went back into the den, den humidity rose to 100% and remained there as long as the rabbit was in the den. This cycle of humidity records, corresponding to the rabbit's location, was repeated three consecutive days. We believe the respiration of the rabbit in the den, a non-permeable box, caused the increased relative humidity.

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The Anthracene-in-Benzene Chemical Light Meter¹

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Abstract

Several researchers have suggested that the anthracene-in-benzene chemical light meter is a useful tool for obtaining integrated solar insolation values. In studies of energy distribution under forest canopies and in small forest openings, the authors found this meter, with modifications, to be surprisingly sensitive and gratifyingly inexpensive. This paper describes the chemical light meter, emphasizing improvements in technique, equipment, and data interpretation, and points out its pertinent limitations. Several applications are discussed.

Introduction

The measurement of solar radiation above, within, and below plant canopies has long been an important endeavor in ecological research. Much effort has been expended to develop economical light measuring devices capable of simultaneously sampling many points (4, 6). Of the methods now in use one of the more popular and useful is the technique for measuring light energy via the photo-conversion of anthracene in benzene solution to dianthracene (1, 3, 5).

Briefly, the technique is based on the fact that anthracene in benzene will polymerize into insoluble dianthracene upon exposure to sunlight. Glass vials of a known concentration of anthracene in benzene are exposed to the light environment of a particular location for a designated period of time and then analyzed to determine the concentration of unconverted anthracene remaining in solution. This analysis is made by filtering the contents of an exposed vial to remove the insoluble dianthracene and then determining the concentration of the remaining anthracene with a spectrophotometer. The decrease in concentration is then related to the amount of light energy received by using a predetermined calibration curve.

Advantages and Limitations

As with any technique certain advantages and limitations must be considered. The anthracene chemical light meter measures the cumulative amount of light energy reaching a particular location over a given period of time without requiring additional recording equipment. The added benefit of small size (*ca.* 1" x 2") allows the researcher to sample almost any location without disturbance. However, instantaneous values of light intensity are unavailable and additional instrumentation, such as a photometer or pyranometer, is necessary if such data are desired.

The technique is relatively inexpensive except for the spectrophotometer, which is available in most laboratories. We have determined,

¹ Journal Paper No. 5398, Purdue University Agricultural Experiment Station.

for example, that after the initial acquisition of a limited amount of glassware, the cost per vial per sample run was about 2 cents. This low cost allows the researcher an almost unlimited number of points which can be sampled simultaneously. However, one cost not included, and a definite drawback of the technique, is the large number of laboratory man-hours required in preparing and analyzing the chemical light meters. We found that a single sample run of 400 meters (vials) would involve about 20 laboratory man-hours.

The most serious limitation of this technique, as well as other proposed chemical light meters, is that the absorption regions of the chemicals used are in ultraviolet light regions, which does not correspond with chlorophyll absorption. The absorption spectrum for anthracene in benzene is less than 390 nm with 100% absorption at about 345 to 360 and at 379 nm. There is no absorption in the visible or near-red spectrums (410 to 1000 nm) (5).

For this meter to be useful as a device for determining total incoming energy over a given time period, it would seem necessary that the ultraviolet light be a constant fraction of that total. According to several authors (6), except for very low energy periods at or near sunrise and sunset, ultraviolet light makes up a nearly constant part of the total daily incoming light energy. However, this relationship may change radically below a plant canopy since some species spectrally modify sunlight as it passes through their foliage. The canopies of some hardwood species, for example, are reported to spectrally modify sunlight; pine canopies on the other hand are more generally regarded to act as neutral filters (2, 6).

Criticism has been voiced about the failure of many light meters, including chemical ones, to quantify directly the photosynthetically active radiation. This may be valid if one intends only to study photosynthesis. However, much attention today is being given to total energy balances, which correspondingly involve the entire spectrum. Although the anthracene chemical light meter is sensitive only in the ultraviolet wavelengths, the meter correlates well with instruments measuring all incoming solar energy (6).

Improvements in the Technique

A literature search failed to reveal the best type of vial to be used. Our studies showed that 20 ml scintillation vials with foil-lined screw caps (Packard Inst. Co.) performed well because of their strength and durability, consistency in spectral properties, prevention of benzene corrosion, and their small size. The problems of leakage and evaporation losses of benzene, experienced by other researchers, were not encountered with these vials. The cardboard shipping trays were also found to make excellent vial holders when inserted into easily designed, wooden light-tight boxes for field use.

Variations in recommended concentration from 0.1 to 6.0 g of anthracene/l of benzene were also found in the literature. Since spectrophotometers cannot usually be used to determine concentrations

much above 0.1 g/l, higher concentrations must first be diluted. Even after a full day's exposure to direct sunlight, we found it necessary to dilute the higher initial concentration solutions before insertion in the spectrophotometer. Since the dilution operation must be performed individually on the contents of each vial after it has been filtered, this is a cumbersome, time-consuming and possibly error-filled process. Rediske *et al.* (5) suggested by-passing the dilution procedure by using a starting concentration near the upper limits of sensitivity of one's spectrophotometer. Figure 1 shows that with 0.1 g/l anthracene in benzene as a starting concentration, the calibration curve for our spectrophotometer was linear over the entire range of interest. Higher concentrations showed the same linear relationship. The light energy flux for use in this calibration curve was determined by an Eppley pyranometer.

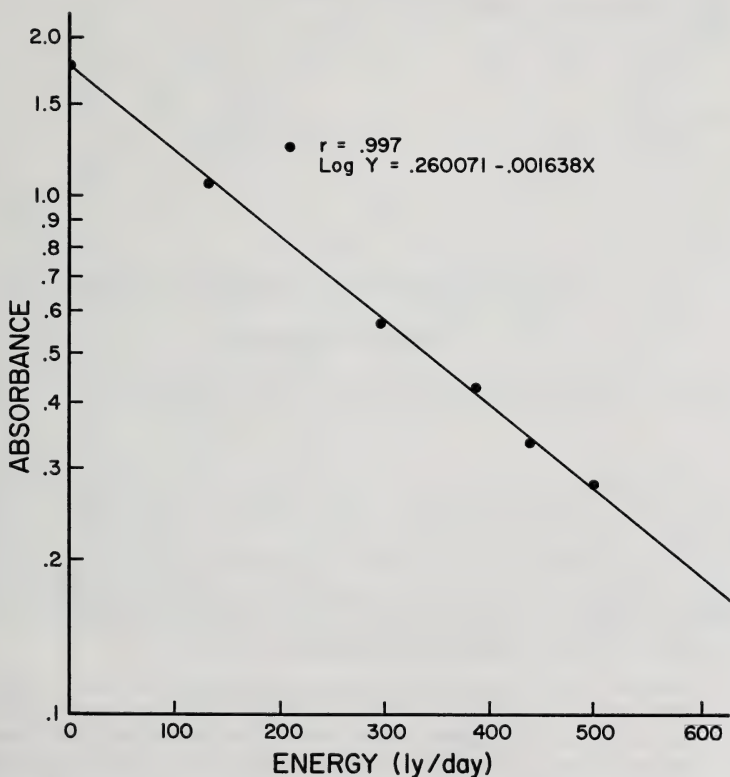


FIGURE 1. Calibration curve showing linear relationship with 0.1 g/l anthracene starting concentration.

A statistical test of the slope of the calibration curve as affected by initial solution concentration showed that slope was not affected (99% confidence level) for initial concentrations of 70, 80, 90 and 100 mg/l.

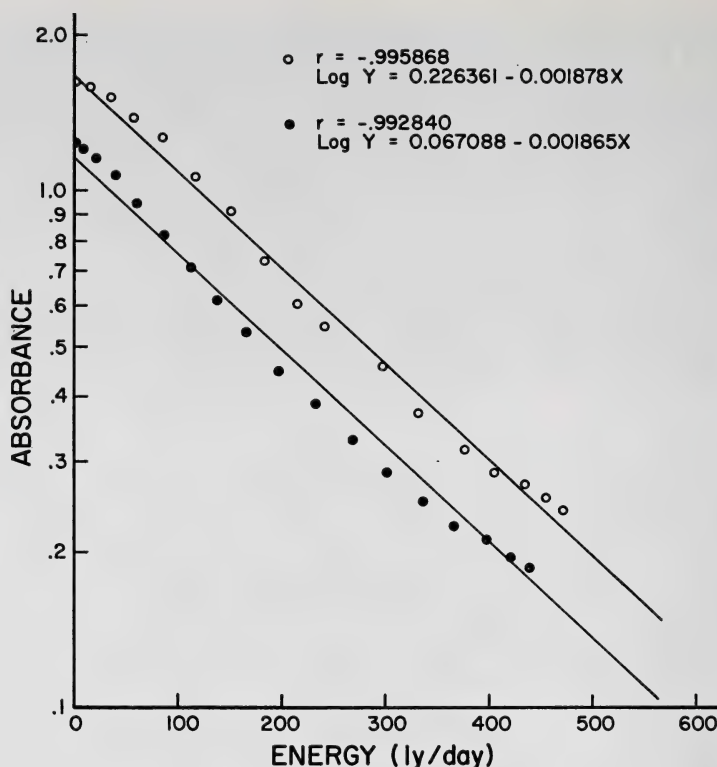


FIGURE 2. Two calibration curves for vials on a burlap background. Upper curve represents 90 mg/l starting concentration and the lower curve represents 70 mg/l starting concentration.

A test was also conducted on the effect on the calibration curve of the type of background over which the vial was exposed during calibration runs. Figures 2 and 3 illustrate these effects for a burlap surface background and the diffuse background surrounding a hanging vial. The two sets of calibration curves have very different slopes. Calibration curves obviously should be determined using the same materials and set-up as that to be followed in the field.

Applications of the Techniques

One of the current research projects of the Department of Forestry and Conservation at Purdue University deals with the light regime in small forest openings. A 50 x 60-foot rectangular opening, long axis aligned north and south, was cut in a 22-year old red pine (*Pinus resinosa*, Ait.) plantation which averages 35 feet tall and has complete crown closure. To determine the levels and patterns of solar energy being received in the opening, chemical light meters were installed along three east-west transects across the opening. To check on the ability of the anthracene meters to accurately measure light

in the shaded portions, an Eppley pyranometer was also located in the opening. Results for a single time period from sunrise to solar noon on a clear day are presented in Table 1. The table shows that the sample points on the west side of the opening did record the most energy as would be expected, as well as a decreasing trend in energy from west to east to a point (-2.0 feet) inside the pine stand. Also shown by the data are the comparable results of the chemical meters located 1.5 feet north and south of the Eppley. Each of these meters measured 44 ly which is within 1 ly of the 45 ly measured by the Eppley.

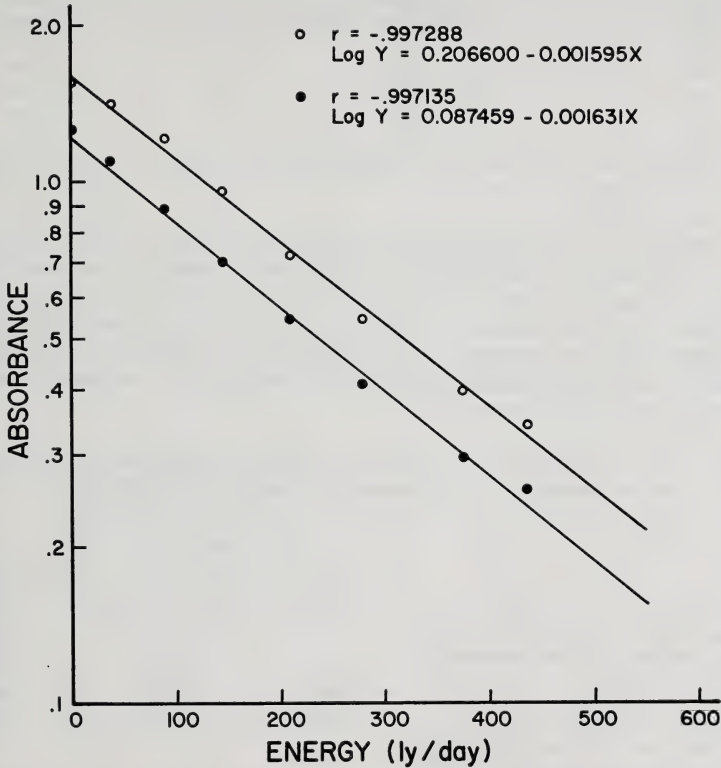


FIGURE 3. Two calibration curves for hanging vials with a diffuse background. Upper curve represents 90 mg/l starting concentration and the lower curve represents 70 mg/l starting concentration.

Another portion of the research is a study of the variability in the daily light energy received under a dense pine forest canopy. In the same red pine plantation as previously described, data were collected using anthracene meters for three separate days. The objective was to sample the variability in relative light intensity so that the proper number of sample points to provide statistical reliability could be calculated.

TABLE 1. *Integrated energy values (in langleys) obtained along east-west transects of a forest opening using chemical light meters. Data obtained for time period from sunrise to solar noon, August 28, 1973.*

Distance of Sample Points from East Edge of Opening in Feet	Location of Transect from South Edge of Opening in Feet		
	28.5	30.0	31.5
—2.0	24	--	24
1.0	53	36	36
2.5	44	45 ¹	44
4.0	47	46	50
7.0	65	--	63
13.0	92	--	92
19.0	112	--	119
25.0	132	--	132
31.0	147	--	144
37.0	130	--	142
43.0	139	--	141
49.0	121	--	123

¹ Obtained with an Eppley Pyranometer

Table 2 gives the summaries of the three sample runs. Mean relative light, which is the percentage of light received in the open, was used so that the three days could be compared successfully. The calculation of the adequate sample size in the last line of Table 2 indicates that the variances of the three test runs were close. These numbers are in good agreement with the estimated 10 samples commonly suggested in the literature.

TABLE 2. *Statistical summary of ground level light measurement data under a 22-year old red pine stand with full canopy closure using chemical light meters.*

	Date of test		
	June 14, 1973	August 4, 1973	August 22, 1973
Sample size -----	20	20	24
Mean relative light as compared to that in the open -----	.0170	.0121	.0128
Coefficient of variation -----	.3529	.3471	.2656
Variance -----	.000036	.000018	.000012
Calculated sample size assuming a 20% error about the true mean, $t \approx 2$	12	12	8

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A Study of Light Distribution within a Red Pine Canopy¹

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Abstract

A three-dimensional sampling scheme was designed to measure daily solar insolation in a red pine plantation. Because of its economical use and convenient size the anthracene-in-benzene chemical light meter was utilized as the energy-sensing device. Fifty-six sampling points were established at each of six height levels on a 1/20-acre plot within the plantation. The variance in light readings obtained between points on each level was used to refine the sampling technique. The pattern of change in solar insolation with increasing canopy depth was then determined.

Introduction

According to Geiger (3) light extinction curves in forest canopies were probably first developed in the 1930's. However, the mathematical relation of light intensity to a foliage parameter was not defined until 1953 when Monsi and Saeki (5) adapted the Beer's-Lambert equation to absorption of light by a plant canopy. During the following decade this basic model was tested primarily on low canopies, such as rice, dwarf fir, and mixed herbaceous systems. Baumgartner (1) found that the light attenuation curves for tree canopies were significantly different from those determined for low canopies. Geiger (3) and Kira *et al.* (4) concluded that tree canopies were a special case.

Few of the models of light attenuation developed up to the present have actually been tested on tree canopies, and the tests which have been made are invariably statistically inadequate. This is due to the extreme difficulty in sampling tree foliage by strata and also due to the economic and physical limitations imposed by most light measurement systems.

Objective

The purpose of this research was to determine the light attenuation curve for a specific tree canopy. It was desired to sample with minimum foliage disturbance and to vary sampling intensity to attain a common error level about the true mean light intensity at each height sampled.

Methods

A 1/20-acre square plot was located in a 22-year old pure red pine (*Pinus resinosa*, Ait.) stand at Cunningham Forest near Linden, Indiana. Crown closure was 100% and the plantation had not been subjected to previous silvicultural treatment. Mean dbh was 5.7 inches, mean height was 35.4 feet, basal area equaled 182 ft²/acre, and stocking was 1020 stems per acre.

The anthracene-in-benzene chemical light meter was selected as the light-measuring instrument because the small vial size permitted

¹ Journal Paper No. 5397, Purdue University Agricultural Experiment Station.

sampling with minimum foliage disturbance and the low cost allowed a large number of observations to be made simultaneously. To adapt this light meter to a vertical stratified sampling scheme, copper wire vial holders were devised which could be hooked into 20 cm rings to be placed at each sampling point within the stand. Tests showed non-significant effects of the rings on the light intensity measured by the vials.

Eight, 150 lb-test nylon lines were placed through the canopy at a 5-foot horizontal spacing at each of 6 stratum heights; 11, 15, 19, 23, 27 and 31 feet. A crossbow was used to string the lines through the canopy so as to alter branch geometry only to a very small degree. Double nylon lines, each with 7 rings spaced 5 feet apart, were then pulled through using the initial lines as guides. Finally, the ringed lines were adjusted to strata heights ± 6 inches and to a 5-foot horizontal spacing ± 1 foot. Because of the combined effects of the sag in the nylon lines and the length of the copper wire vial holders the actual strata heights for light sampling were: 10, 14, 18, 22, 26, and 30 feet. This system of lines provided 56 potential sampling points at each stratum height.

Heads for a sectioned aluminum pole were devised to hang and to retrieve the vials in the wire holders. Ground level measurements were made by using burlap covered wood blocks to which vials were wired.

To permit comparisons of light intensities measured on different days, only clear, relatively cloudless conditions were desired. Measurements were made on June 14, July 12, August 4, and August 22. The range of incoming light energy on these days was from 498 to 567 ly. Anthracene concentration was 100 mg/l for all runs except on July 12 when it was varied to 3 g/l, thereby permitting a test of the effect of concentration on energy recorded. The 125-175 vials used for each measurement run were put in place either in the early or late daylight hours and then taken down in the same sequence after a daylength exposure to light. In each run sample points were assigned randomly over the 56 possible points of each stratum. Initially, 25 observations were taken per stratum, but after the first run analysis showed that the 10- and 14-foot strata were not significantly different from the ground level and they were deleted from the third and fourth sampling periods. Also, sample sizes to attain a common 20% error about the mean were calculated, and in succeeding runs strata sample sizes were adjusted as could be accommodated within experimental limitations. In the third run a 34-foot stratum with 24 points was also used.

Values for incoming light were obtained using 8 vials and an Eppley pyranometer placed on top of a 45-foot tower 200 feet from the light measurement plot. A Rustrak recorder connected to the Eppley provided additionally a permanent record of energy variability.

Results

Energy data were first converted to per cent of incoming light (relative light intensity) so that separate days could be compared

successfully. The distributions of observations by stratum within runs were tested using the Kolomogorov-Smirnov test (6) and found to generally fulfill the desired normality assumption although the data of the 22- and 26-foot strata in all four runs were more exponential than normal. The variance values within each run increased with the means, and ranges of values from similar population sizes increased generally with the means. Consequently, a logarithm transformation was done before converting to per cent of incoming light. This had the effect of making variances much more independent of the means and more homogeneous. Coefficient of variation values of each stratum were compared between runs using the Foster-Burr Q test (2) and found acceptably homogeneous by stratum with Run 2 omitted.

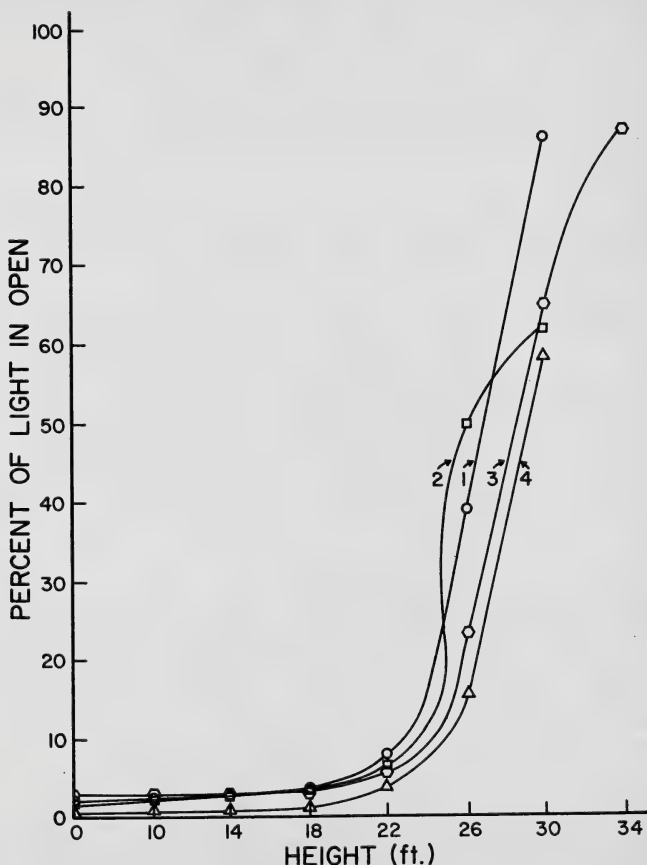


FIGURE 1. A comparison of mean light intensity for 4 days in the light measurement plot. Run numbers 1-4 are chronological.

An analysis of variance using the transformed data showed that height in the canopy had a highly significant effect on the light received. A Newman-Keuls sequential range test (7) then showed that

stratum means from 26, 30 and 34 feet in all runs were significantly different at the 0.01 level both from each other and from all lower strata. In none of the runs were the ground, 10, 14 and 18-foot levels significantly different at the 0.05 level. When mean light by stratum was graphed as per cent of incoming light (Fig. 1), Runs 1, 3, and 4 showed similar form with possible increase in rate of attenuation with lateness in the growing season. Run 2 represented a higher anthracene concentration and was not considered typical. Runs 3 and 4 when compared using Student's *t* test (7) showed significant differences in mean light intensities at the 22 and 26-foot heights. Accumulated from the top, per cent light intensity averaged from Runs 3 and 4 plotted against height approximated a smooth sigmoid curve (Fig. 2).

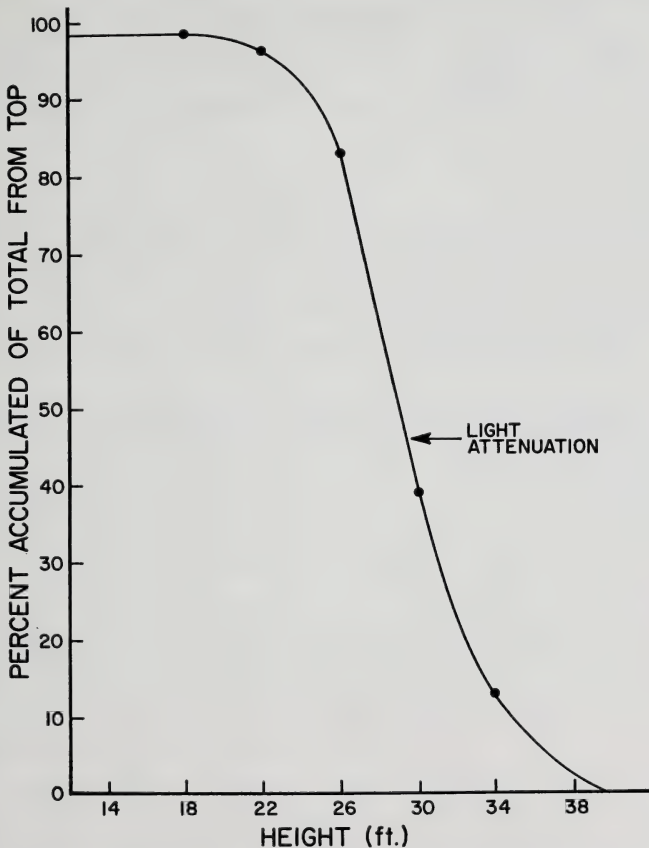


FIGURE 2. *The light attenuation summary curve for Runs 3 and 4.*

Using coefficient of variation values in an iterative procedure to determine sample sizes, the 22-foot strata invariably required more than 56 points to achieve a 20% error about the mean. Because of limitations in time and labor and a desire to sample all strata proportionately, a maximum of 37 points was used at the 22-foot level.

Conclusion

Given a light attenuation curve for a canopy, extinction coefficients for the rate of light decrease could be determined for each height stratum. A beam of light with a given angle of canopy penetration would therefore pass through calculable path lengths for each stratum and be attenuated to a determinable degree. Consequent predictions of the amount of incoming solar energy received for a day or a season through measureable depths of canopy could be useful in estimating forest energy balances.

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An Ecological Inventory of Bryan Nature Preserve

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Abstract

Bryan Nature Preserve, one of the natural areas protected under the Indiana Nature Preserve Act, is a 29-acre, old-growth, oak-hickory, beech-maple forest located in Clinton County. The habitat is variable, ranging from wet to dry sites and from old-growth forest to old field.

Flora and fauna of the preserve are quite diverse including 200 species of plants, 74 species of birds during spring and fall migrations with 22 species present year-round, 5 species of amphibians, 4 species of reptiles, and 17 species of mammals.

The dominant overstory species are *Quercus alba*, *Q. rubra* and *Carya ovata*. However, the sapling-sized understory is dominated by *Acer saccharum* and moderate numbers of *Fagus grandifolia*. In the absence of disturbance these two species will probably replace the present overstory dominants.

Introduction

Bryan Nature Preserve is a 29-acre, relatively undisturbed, old-growth, deciduous forest located 8 miles northwest of Frankfort, Indiana, in Clinton County. Twenty-seven of the 29 acres are forested, with the remainder in early successional old fields. A few remaining stumps are evidence of past selective logging conducted more than 30 years ago.

Bryan Nature Preserve occurs on the Tipton Till Plain or Central Drift Plain formed during the Wisconsin Glacial Era 10,000 to 12,000 years ago (6). The till plain is composed of approximately 100 to 130 feet of glacial till over sandstone and shale bedrock in Clinton County. Wet depressional areas are common throughout the relatively level (<10 feet elevation change) plain. Surface drainage is poorly developed on the Tipton Till Plain and none occurs from Bryan Nature Preserve.

The two soil types present in Bryan Nature Preserve are Ragsdale silty clay loam and Fincastle silt loam. The Fincastle is a somewhat poorly-drained soil developed from loess (wind-blown silt) over glacial till and comprises the upland, better-drained soil in the forest. The Ragsdale is a very poorly-drained soil developed from loess and frequently supports a suspended water table.

Previous studies of Bryan Nature Preserve have been limited to small sample areas (1, 3). The greater importance of oak and hickory tree species compared to beech and maple was pointed out in these studies. Fifty-nine forb species were recorded as present by Jones (3). Other flora and fauna species have not been studied.

The main objective of our study of Bryan Nature Preserve was to obtain baseline data of plant species composition (herbaceous and woody understory and overstory) and animal species of the area. These data will be used as a means of comparison for studying man's

effect on the area over time, as well as background information for future research in the preserve.

Methods

The forest was divided into 0.1-hectare (0.246-acre) quadrats (100 x 107 feet) and permanently marked with steel pipe and aluminum tags. Quadrats were numbered consecutively, starting in the north-west corner of the preserve.

Boundaries and total acreage of standing water in the three large depressional areas were determined for each season during 1972. Delineation of the different soil types was provided by the Soil Conservation Service, United States Department of Agriculture.

Composition of woody vegetation in Bryan was determined by a total inventory of the mature trees (>4.9 inches diameter breast high) and a partial sampling of shrubs and saplings (>4.5 feet in height but <4.9 inches dbh). Data for each mature tree were recorded on Fortran coding paper as follows: Date, quadrat, tree number, species, dbh (diameter breast high—determined by diameter tape), crown condition, and presence of forks, vines, and dens. Dominant, codominant, suppressed, and understory comprised the crown classes. The presence of forks and dens was recorded as either above or below breast height (4.5 feet), and vines were divided into above 1-inch diameter and below 1-inch diameter classes. The presence of dead trees and cut stumps in each quadrat was also recorded.

These data were used to compute basal area and density by species for each quadrat and for the entire forested area (4). The sum of relative basal area and relative density divided by 2 gave an importance value by species. The density of shrub and tree saplings was determined using strip quadrats of 3.28 feet (1 m) by 100 feet (30.4 m) located on the west boundary of each large quadrat.

Specimens of herbaceous plant species were collected at the time of flowering and recorded by community type. Gray's Manual of Botany was used in identification of the plants (2).

Throughout the study (January 1972-September 1972), general observations were made of the forest fauna. Visits were made to the woods at least once a week and usually more often. Mammals sighted and mammal signs were recorded each time, thus giving a reasonable indication of those mammals present during the year. Bird species were observed throughout the period with special attention given to the year-round resident birds, migrating spring and fall birds, summer residents, and the raptors seen flying over the woods. Birds were identified through actual sightings as well as by song. Amphibians and reptiles observed were also identified and recorded.

Results

Standing Water

The area inundated during February 1972, was 1.1 acres (Fig. 1). This area increased to 3.3 acres by April due to snowmelt and spring

rains. Numerous other very small depressional areas were inundated but are not included in the above estimates. The two depressional areas located in the northwestern and southwestern corners of the preserve were dry by mid-July. The large depressional area was dry by August 25 but remained so only until September 7.

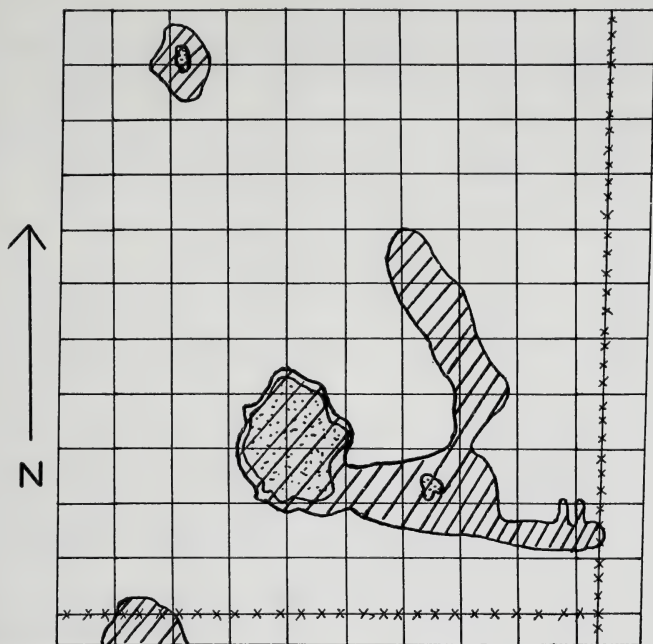


FIGURE 1. Standing water in Bryan Nature Preserve during February (stippled) and April (hatched) of 1972. One grid square represents 1/10 hectare except for the odd-sized ones along the fence line (x-marked) and along the west boundary.

Distributional patterns of plant species correspond very closely to the area inundated during April. This probably indicates that the area inundated in the spring of 1972 is approximately the maximum that occurs during any given year.

Plant Communities

There are three major plant community types in the preserve (Table 1). These correspond to edaphic factors or to past disturbance. The forest mesic and forest wet communities correspond to the areas free of inundation and the areas inundated during part of the year, respectively (Fig. 1). The open field community type corresponds to a recently cultivated area located along the eastern edge from the fence to the east boundary.

Other less extensive community types also occur. The wet depressional area in the southwestern corner is more open and more recently disturbed than the other wet areas. It is characterized by water-plantain

(*Alisma triviale*) and common cattail (*Typha latifolia*). The western part of the east central wet area is surrounded by wet-site tree species such as pin oak (*Quercus palustris*) and swamp-white oak (*Quercus bicolor*). However, the deeper portion contains water much of the year and is dominated by the high shrub, buttonbush (*Cephalanthus occidentalis*).

TABLE 1. Number of plant species and families identified according to habitat type.

Vegetation Type	Number of Species		
	Forest Mesic	Forest Wet	Old-field
Herbs -----	76	20	68
Shrubs -----	14	2	7 ¹
Vines -----	6	0	1
Trees -----	25	9	7 ¹
Total Species -----	121	31	69
Total Families -----	55	18	25

¹ Intensive sampling of old-field communities has not been made for tree and shrub seedlings.

The greatest number of species occurs in the forest mesic community type (Table 1). Total number of species identified is four times greater in this type than in the wet community type and about twice as large as the open field type. The mesic community type, however, includes the transitional areas along the forest edge and along the water boundaries and therefore includes species from the other two types.

The number of species will probably increase as more intensive studies are made. For example, the open field has not been sampled for tree and shrub seedlings which are known to occur.

A complete listing of plant species by community type can be obtained from the Department of Forestry and Conservation, Purdue University.

Trees

White oak (*Quercus alba*) is the most important tree species found on the area (Table 2). This is due to both its abundance and large size. It is the fourth most abundant tree, with 158 stems, 68% of which are ≥ 20 inches dbh. White ash (*Fraxinus americana*) has the second highest importance value primarily because it is the most abundant with 366 stems. Sixty-two per cent of these are ≤ 10 inches dbh. Only 12 stems are ≥ 20 inches dbh. A large number of individuals for this species occurs along the forest edge.

Sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*) are relatively unimportant in the overstory. However, American beech is more important than sugar maple both in total stem number and in size of stems. Sugar maple had a total of 38 stems, 10 of which are ≥ 20 inches dbh. American beech had a total of 78 stems with 41 ≥ 20 inches dbh.

TABLE 2. Vegetational attributes¹ of Bryan Nature Preserve based on complete tally of all stems greater than 4.9 inches diameter breast high and ranked in order of decreasing importance value.

Species	B ₂	B ₃	D ₂	D ₃	V ₃
<i>Quercus alba</i> -----	31.22	24.90	6.08	7.58	16.24
<i>Fraxinus americana</i> -----	8.81	6.63	14.08	17.55	12.09
<i>Quercus rubra</i> -----	19.06	15.20	5.19	6.47	10.84
<i>Carya ovata</i> -----	11.59	9.24	10.81	13.46	11.35
<i>Tilia americana</i> -----	6.30	5.03	9.81	12.23	8.63
<i>Quercus bicolor</i> -----	9.53	7.60	2.81	3.50	5.55
<i>Quercus palustris</i> -----	9.22	7.35	1.96	2.44	4.90
<i>Fagus grandifolia</i> -----	7.01	5.59	3.00	3.74	4.67
<i>Juglans nigra</i> -----	4.41	3.52	3.00	3.74	3.63
<i>Ulmus americana</i> -----	1.57	1.25	3.96	4.94	3.10
<i>Carya glabra</i> -----	2.43	1.94	2.81	3.50	2.72
<i>Acer rubrum</i> -----	3.03	2.42	1.81	2.26	2.34
<i>Ostrya virginiana</i> -----	0.70	0.56	3.31	4.13	2.34
<i>Carya cordiformis</i> -----	1.39	1.11	1.81	2.26	1.69
<i>Acer saccharum</i> -----	1.76	1.40	1.46	1.82	1.61
<i>Prunus serotina</i> -----	0.85	0.68	2.04	2.54	1.61
<i>Quercus macrocarpa</i> -----	2.78	2.22	0.77	0.96	1.59
Remaining 16 sp. ² -----	4.21	3.36	5.52	6.88	5.10
Total	125.37	100.00	80.23	100.00	100.00

¹ Total acreage covered=26.8 acres. B₂ is basal area (ft² per acre), B₃ is relative basal area (%), D₂ is density (stems per acre), D₃ is relative density (%) and V₃ is the importance value, or the average of B₃ and D₃ for each species.

² Other species in decreasing order of V₃ are as follows: *Celtis occidentalis*, *Liriodendron tulipifera*, *Sassafras albidum*, *Quercus velutina*, *Quercus muehlenbergii*, *Plantanus occidentalis*, *Ulmus rubra*, *Cornus florida*, *Quercus shumardii*, *Fraxinus nigra*, *Carpinus caroliniana*, *Fraxinus pennsylvanica*, *Gleditsia triacanthos*, *Gymnocladus dioicus*, *Acer saccharinum*, *Nyssa sylvatica*.

The total basal area for all species is 125.4 square feet per acre, a value which is high for Indiana forests. Total density for all species on the area is 80.2 stems per acre.

Tree Saplings

Sugar maple and white ash are the two most abundant species in the sapling size class (>4.5 feet in height and <4.9 inches dbh). The first averaged 238 stems per acre over the entire forest while the latter averaged 172 stems per acre. Sugar maple saplings were well-distributed throughout the interior, better-drained portion of the forest. White ash saplings were found largely along the forest edge. Several of the white ash saplings found in the interior were dead or dying.

American beech saplings averaged 32 stems per acre for the entire forest. These were highly clumped around large individuals and most are believed to be root sprouts.

White oak, the most important overstory tree, appears to be reproducing very poorly in this forest. This species averaged 1 sapling per acre for the whole forest, and most of its saplings were found along the edge between old field and forest.

Fauna

Five amphibian, 4 reptile and 17 mammal species have been identified in the area. These numbers are only a first approximation, however, since intensive studies have not been conducted. One unusual find was a pregnant Keen's myotis bat (*Myotis keenii*), the first to be recorded in Indiana.

At least 22 bird species reside in the preserve year-round, but a more likely estimate would be 38. A total of 74 species have been observed during spring migration. The uncommon veery (*Hylocichla fuscescens*) was sighted during spring migration and the Black-throated green warbler (*Dendroica virens*) was sighted in June, a rare occurrence this far south during the summer months.

Lists of faunal species can be obtained upon request.

Discussion

The secondary successional pattern for mesic forests of west-central Indiana is believed to proceed from oak-hickory to oak-maple to maple-oak to maple-beech to beech-maple and finally to a beech-dominated mixed-mesophytic forest (5). The high number of sugar maple saplings and moderate number of American beech saplings compared to other species indicate that, barring large-scale disturbance, the mesic community type of Bryan Nature Preserve will follow this pattern. Future change in species composition of wet sites is more difficult to predict. However, red maple is a species likely to become more abundant as pin oak and swamp white oak trees die, due to its prolific seed production and fast growth.

Acknowledgments

We would like to express our gratitude to Dr. R. E. Mumford, Dr. David A. Easterla, and Mrs. Rastrigan, Purdue University, for their help in species identification or for provision of other information which enabled us to fulfill the objectives of this study.

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Potential of the White Amur (*Ctenopharyngodon idella* Val.) as a Biological Control for Aquatic Weeds in Indiana¹

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Abstract

Six-inch white amurs (*Ctenopharyngodon idella* Val.) were maintained in greenhouse aquaria and barrels to study their potential as biological control agents for aquatic weeds. The fish were subjected to a variety of plant and animal diets, exposed to varying concentrations of rotenone, and the water in which they were growing was tested for nutrients released by fish defecation. Results show that the fish will eat many common Indiana weeds, including several *Potamogeton* species, *Ceratophyllum Lemna*, filamentous algae, and others. The fish also consumed all animal material presented. The monitored nutrients increased over a 25-day period with largest increases occurring in ammonia and nitrate levels. The fish were very sensitive to concentrations of rotenone as low as 6×10^{-3} parts per million.

Introduction

Many Indiana ponds and lakes have become infested with aquatic vegetation to the extent that they are no longer useful as recreational areas unless vegetation control practices are utilized. Indiana farm pond owners and lake association groups now rely primarily on either mechanical harvesters or the application of a herbicide at least once each season to insure reasonably weed-free waters. These methods have their limitations, however. Mechanical harvesters are expensive for the individual pond owner, and chemical treatment, although often effective, can be expensive since retreatment is frequently required. Fish kills caused by plant decay and the concomitant oxygen depletion of the water sometimes accompany chemical treatment.

In 1963, researchers at the U.S.D.A. Fish Farm Experimental Station in Stuttgart, Arkansas, began investigating the potential of *Ctenopharyngodon idella* (variously known as the white amur, Chinese carp or grass carp) as a biological control for aquatic weeds. In these studies the fish proved not only to dispose of aquatic plants and to lack the undesirable attributes of the common carp, but it also possessed many desirable qualities: "An informal taste panel . . . rated the white amur second only to red snapper, and better than catfish, bass, and trout. With weights exceeding 100 pounds, this fish has tremendous possibilities with the American fisherman. It has been caught on popping bugs, pellets, grass, worms, and other similar baits, and when hooked, it exhibits terrific fighting capabilities. It is able to withstand a wide range of water temperatures from 0° to 35°C, can tolerate salinities as high as 10,000 ppm and can withstand oxygen concentration as low as 0.5 ppm" (4).

Although the amur has been released in certain Arkansas lakes for weed control, most states including Indiana have banned the importation

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of the fish until both short-term and long-term studies can be conducted on its effects on the aquatic ecosystem of each geographic area. In the fall of 1972, we obtained a special permit from the Indiana Department of Natural Resources to import 20 amurs for study in indoor aquaria. The general purpose of the indoor study was to investigate the amur's potential for controlling Indiana aquatic weeds. The study also was designed to pinpoint some of the problems the amur might cause in an aquatic environment before it is actually introduced to an outdoor site. The specific objectives of the study were to determine: 1) the food preferences of the amur among aquatic weeds common to Indiana; 2) the ability of the fish to eat living animal material as well as plant material; 3) the potential of the amur to release plant nutrients into the water; and 4) its sensitivity to the fish toxicant rotenone.

Methods

Twenty six-inch (15 cm) white amurs were obtained from the Arkansas Fish and Game Commission, Little Rock, Arkansas, and were housed in either 15 gal glass aquaria or in 17 gal plastic-lined barrels. The containers, located in the greenhouse, were equipped with sub-sand filters and an oxygen supply.

Aquatic plant and animal materials to be used in the food trials were collected from farm ponds in the Lafayette and Crawfordsville areas. In the plant preference trials, the fish were given weighed amounts of three aquatic weed species, and the order of disappearance of the species from the barrel was noted to determine the weed preferences of the fish and whether any weed was rejected completely. Various combinations of weed species were provided for each fish. In the animal feed trials, the fish were placed in aquaria with both a highly preferred plant species (*Potamogeton crispus*) and test animals to provide the amurs with a choice of food types. Animals tested included American toad tadpoles (*Bufo americanus*), red worms (*Bimastus* sp.), $\frac{1}{2}$ -inch and $1\frac{1}{2}$ -inch minnows (*Notropis* sp.), and mayfly (*Ephemera*) and dragonfly (*Anax*) nymphs.

Nutrient release studies were conducted on water samples collected every 5 days from barrels. Each barrel contained one amur and a mixture of three plant species: *Lemna minor*, *Elodea canadensis*, and *Potamogeton foliosus*. Nitrate was measured using the cadmium reduction method (7), ammonia was tested with a Hach Model NI-8 Ammonium Nitrogen Test Kit, phosphate phosphorus by the ascorbic acid method (7), and potassium with a National Instrument Laboratories Sodium-Potassium flame photometer. Temperature and pH were also monitored.

The rotenone studies were conducted using white amurs, black bullheads (*Ictalurus melas*) and green sunfish (*Lepomis cyanellus*) in glass aquaria. Rotenone (90% powder, Sigma) concentrations used were 4×10^{-3} , 6×10^{-3} , 8×10^{-3} , and 10^{-2} ppm. The fish were exposed for a period of 24 hours.

Results

The white amurs (Fig. 1) ate all plants placed in the barrels including both higher aquatic species and filamentous algae. They did, however, show a decided preference for those plants with tender leafy shoots rather than either plants with coarser, thinner leaves or filamentous algae. In addition, the fish ate the leaves of the plants first, leaving the stems and apical meristems intact. Only if the fish were not provided with more fresh plant food did they begin to eat the stems of the plants. Of all of the plants, the filamentous blue-green alga *Lyngbya*, which forms a thick black mat on the surface of the water, was least preferred by the fish although it, too, was eventually eaten when no other food was provided. The plants in order of preference (* indicates filamentous algae) were *Elodea canadensis*, *Chara* sp., *Potamogeton crispus*, *Lemna minor*, *Potamogeton foliosus*, *Najas flexilis*, *Pithophora*,* *Ceratophyllum demersum*, *Sirogonium*,* and *Lyngbya*.* Other common Indiana weeds which were readily eaten but not included in the preference test were *Potamogeton pusillus*, *Myriophyllum* sp., *Wolffia columbiana*, and *Azolla* sp.



FIGURE 1. The white amur (*Ctenopharyngodon idella* Val.) 2/3 actual size.

Even though the amurs ate continually as long as plant food was provided, the fish did not show the weight and length gains which might be expected. In fact, over a period of 3 months of active feeding, the fish gained only an average of 5 g in weight and 1 cm in length. The small weight and length gains were undoubtedly due to the small size of the barrels and aquaria in which the fish were housed. Most of the plant food consumed was passed as fecal material which caused the water to become very turbid after only a week of active feeding. Microscopic examination of the fecal material showed it to consist mainly of chunks of unbroken cells and plant tissue.

The food tests indicated that the amur will readily eat animal material. In almost all cases, when the animal material was added to the tanks containing amurs and one of their favorite plant foods, curly leaf pondweed (*Potamogeton crispus*), the fish immediately turned to the animals and ate them. The fish did not consume the larger 1½-inch *Notropis* minnows but did eat the smaller ones. The amurs did not eat the tadpoles immediately. The curly leaf pondweed was eaten first over a period of 10 days and then the fish consumed the tadpoles once the curly leaf was gone. To check the possibility that the amurs were attracted to the animals because of their movement in the water, dead red worms were added to the aquaria. However, the amurs also ate these moribund organisms.

The nutrient release studies indicate that all of the nutrients except phosphate increased in the water (Fig. 2). Over a period of 25 days, the ammonia increased by more than 1600%, nitrate by 1100% and potassium by 970%. Although the overall phosphate levels generally decreased by 32% over the initial measurements, the levels began to increase gradually at 20 days. The decrease shown by phosphate may have been due to the extreme hardness of the water, so that phosphate was gradually precipitated as calcium phosphate, or by the removal of the phosphate by microscopic algae present in the water.

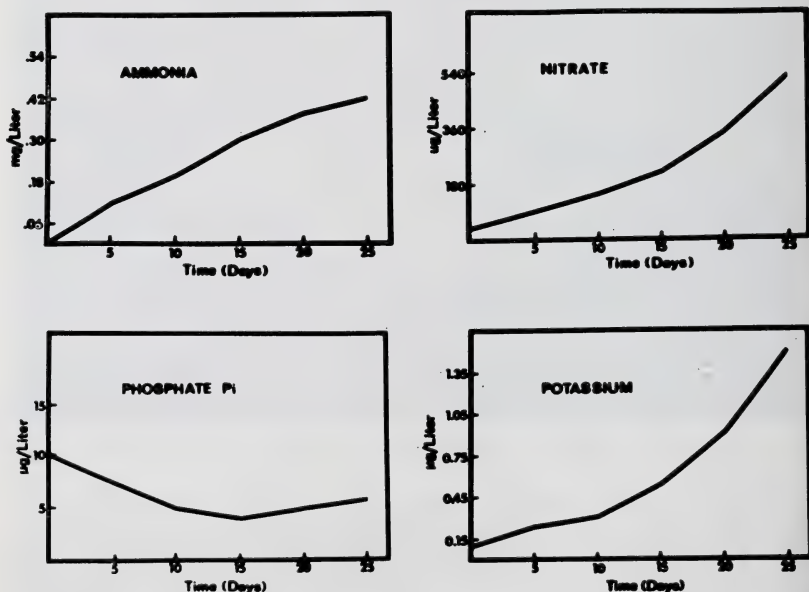


FIGURE 2. Measurements of nutrient release into the water by the white amur.

The amurs appeared to be very sensitive to rotenone and began to show stress at the lowest concentration of rotenone used, 6×10^{-3} ppm, after 3 hours exposure. However, by 24 hours the fish had recovered and were swimming normally. At 8×10^{-3} and 10^{-2} ppm, the

fish actually came to the surface of the water and were floating on their sides after 4-5 hours. After 24 hours, the fish had recovered and were swimming normally. The catfish and bluegills were not affected by any of the concentrations of rotenone used.

Discussion

The results of this study agree with those of other researchers (2, 3) who have found that the white amur will eat almost any aquatic plant material. The amurs in our study consumed all plant material either free-floating or rooted except for microscopic algae in the water and short filamentous algal growths on the sides of the barrels. The amur masticates its food by pharyngeal teeth which grind the food against a hard pad in the throat. The fish is not equipped to consume microscopic or bloom-forming algae (3). Consequently, the amur could not be used to control blue-green algal blooms which are common to many Indiana lakes.

The lack of incorporation of the plant material into fish flesh was also noted by other researchers (5, 8). Although in our study, the fish were stunted by the small containers and passed most of the food consumed as feces, Hickling (5) noted that digestion is incomplete even in those fish maintained in the field and growing rapidly. About half of the food material is passed out as feces; the fish digest only the contents of those cells which have been broken by mastication. The large amounts of undigested and partially digested plant material re-entering the water could thus provide a ready source of nutrients for plant growth. Although the amur would be expected to control the higher plant and filamentous algal growths, it could not control blue-green blooms which might be stimulated by the additional nutrient inputs. The nutrient studies indicate that nitrate, ammonia, and potassium, all forms readily utilized by blue-green algae, are released into the water by the amur. Although our tests were conducted in a small, closed system which is not at all indicative of a large, open, field situation, the fact that the fish does defecate such large quantities of plant material and nutrients into the water indicates that the fish is limited both in its ability to convert plant material into animal material and in removing excess nutrients from the water.

Several investigators maintain that the amur is exclusively a vegetarian at lengths greater than 6 inches (3, 6). In fact, Bailey (3) states that even after most of the vegetation has been cleared from a pond, the fish still do not turn to animal matter. However, studies conducted in Missouri (1) indicate that the amur prefers freshwater shrimp to plants and eats plants only if they are the only choice. These tests, like ours, were conducted in aquaria rather than in the field and may be prejudiced by the fact that the fish could not help but notice the animal material in the aquarium. In addition, the Missouri tests were conducted on 3-inch fish which might be expected to be omnivorous. Aquarium studies have not, to our knowledge, been conducted on amurs larger than 6 inches although our studies on 6-

inch amurs indicate that the fish have a preference for animal food over plant material.

Bailey (3) observed that amurs appeared to be very sensitive to rotenone, a generally used fish toxicant. He noted 100% kill of 4-inch amurs in aquaria with 6.4×10^{-3} ppm rotenone. This concentration is considerably lower than the dosage recommended by the U.S. Bureau of Sport Fisheries for complete kill of native game species (0.05 ppm). Our tests confirmed Bailey's results and showed that 6-inch fish are sensitive (although not killed) by 6.0×10^{-3} ppm rotenone. This observation may have practical consequences for controlling amurs in a body of water. If the fish can be stunned with low concentrations of rotenone once they have removed the vegetation from a pond, it may be possible to remove the fish from the water, revive them in fresh water, and use them again in another pond or lake. Stunning the fish is desirable for their removal from a pond particularly since the fish are very excitable, and when seined have been known to thrash and jump about violently and injure net handlers.

Unfortunately, indoor aquaria studies can only indicate some of the problems and potentials of the white amur for controlling aquatic weeds and point out some of the areas which require further study. Determination of how the fish will affect the aquatic ecosystem awaits outdoor testing in a closely monitored natural environment. Hopefully, this kind of study will be conducted in conjunction with the Indiana Department of Natural Resources within the next few years.

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Food Habits of Adult Alewives in Lake Michigan Near Michigan City, Indiana, in 1971 and 1972

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Abstract

Food habits of alewives, *Alosa pseudoharengus*, ranging in size from 120 to 199 millimeters, collected along a transect in Lake Michigan near Michigan City, Indiana, were examined from June to October 1971, and May to September 1972. Fish were collected by gill netting or trawling at station depths ranging from 5 to 15 meters.

Zooplankton comprised the major portion of the alewife diet in both years. The copepod *Cyclops bicuspidatus* was the main zooplankton consumed. *Bosmina longirostris* and *Euryccercus lamellatus* were predominant cladoceran food items. Mean per cent volume of copepods and cladocerans in stomachs were similar in 1971 and 1972. Major non-zooplankton food items were chironomid larvae (*Cryptochironomus* and *Chironomus*) and larval alewives.

Seasonal changes in food habits were noted. Per cent volume of zooplankton and cladocera in stomachs increased to maxima in July followed by a general decline for the remainder of each year. Copepods were the dominant food item in June. Chironomid larvae were a major component of the diet in May 1972, and August of both years. The largest per cent volume of alewife larvae in stomachs occurred in September.

Introduction

General food habit studies of fishes are necessary for an adequate understanding of both inter- and intraspecific competition. Likewise, they yield significant information on the direct and indirect effects that a fish species may have on plankton, benthos or fish populations.

Rhodes (2) investigated alewife food habits for the Indiana waters of Lake Michigan in 1970. The present study was based upon Rhodes' work and was designed to deal in greater depth with food habits in relation to daily alewife movement patterns. Only food habits are reported herein.

Methods and Materials

Alewives were collected monthly at depths of 5, 10, and 15 m along a transect in Lake Michigan near Michigan City, Indiana. Gill net collections were made from June to October 1971, and May to September 1972. Nets were set parallel to shore for about 1 hour at sunrise, noon, sunset, and midnight in 1971 and at noon and midnight in 1972. A 16-foot bottom trawl was also used in 1971.

Stomachs were removed soon after capture from a minimum of two alewives per 5 mm length increment. A minimum of 20 stomachs were taken per collection. All stomachs were labeled, placed in cheesecloth and preserved in 10% formalin. Only stomachs which contained fish, fish eggs, chironomids, *Pontoporeia*, or a minimum of 300 identifiable microcrustaceans were included in the analysis. A maximum of 20 stomachs were examined per time period per day. These stomachs

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were selected by using a table of random numbers if more than 20 per category were available.

Stomachs which contained a minimum of 300 identifiable microcrustaceans were subsampled with a Henson-Stempel pipet and examined in a plexiglass counting cell at concentrations of 0.5-6.0% of total stomach contents. Stomachs not containing 300 identifiable microcrustaceans were examined at concentrations of 20-100%.

Food item volumes were determined indirectly using a method reported by McComish (1). Individual species were assigned a geometric figure which approximated their shape and measurements of about 30 specimens of each species were made with an ocular micrometer. The mean volume for each species was then calculated from these 30 measurements.

Plankton samples were taken adjacent to nets for correlation with alewife food habits in 1972. Plankton was collected with a Clarke-Bumpus high speed plankton sampler fitted with No. 20 bolting cloth.

Results and Discussion

Annual Changes in Food Habits

Eurycercus lamellatus was the most important cladoceran consumed in 1971 (Table 1), but *Bosmina longirostris* predominated in 1972. The mean per cent volume for *B. longirostris* was less than half the per cent volume reported by Rhodes (2) for 1972.

Cyclops bicuspidatus was the largest single food item consumed in 1972 followed closely by larval alewives. In 1971 the reverse was true. The 15% volume for 1971-72, approximately equaled the 18% reported consumed by alewives in 1970 (2).

Epischura lacustris was the main calanoid copepod in the 1971 diet while *Eurytemora affinis* was the predominant calanoid consumed in 1972. These two species composed 3% of the total 4% volume of all calanoids in 1971 and 2% of the total 3% volume in 1972. Mean percentage volumes of these two species in stomachs were similar to those reported by Rhodes (2).

Alewife larvae and eggs, but particularly larvae, constituted a large portion of the alewife diet. Larvae composed 20% of the mean volume of all food items while eggs amounted to 1%. Chironomids and alewife larvae were largely responsible for major differences in per cent volumes of food items reported in this study and that by Rhodes (2) who found no larval fish in stomachs.

In addition to the items discussed above, many other prey species formed a portion of the alewife diet. These items included: the cladocerans *Alona affinis*, *Bosmina coregoni*, *Ceriodaphnia* spp., *Chydorus sphaericus*, *Daphnia galeata*, *D. retrocurva*, *Diaphanosoma brachyurum*, *Holopedium gibberum*, *Leptodora kindtii*, and *Polyphemus pediculus*; the cyclopoid copepods *Cyclops vernalis*, *Eucyclops agilis*, and *Tropocyclops prasinus*; the calanoid copepods *Diaptomus* spp., *Limnocalanus macrurus*, and *Senecella calanoides*; harpacticoids; the malacostracan

Pontoporeia affinis; the chironomid larvae *Monodiamesa tuberculata*, *Paracladopelma nereis*, *P. cf. obscura*, *Polypedilum cf. scalaenum*, *Potthastia longimanus*, *Procladius cfr. bellus*, and *Psectrocladius* sp.; chironomid pupae; hydracarinans; turbellarians; nematodes; and the gastropods *Bulimus* sp. and *Valvata* sp. (3).

TABLE 1. Yearly per cent volume and per cent frequency of occurrence (parenthesis) of stomach contents of alewives collected in Lake Michigan near Michigan City, Indiana, 1971-72.

Organisms	1971	1972	Mean
Zooplankton -----	41 (88)	35 (90)	38 (89)
Cladocera -----	23 (75)	12 (66)	18 (70)
<i>Bosmina longirostris</i> -----	3 (52)	5 (60)	4 (56)
<i>Eurycerus lamellatus</i> -----	9 (41)	3 (13)	6 (27)
Copepoda -----	18 (83)	23 (75)	21 (79)
Cyclopoida -----	12 (80)	20 (72)	16 (76)
<i>Cyclops bicuspidatus</i> -----	11 (80)	20 (72)	15 (76)
Calanoida -----	4 (41)	3 (23)	3 (32)
<i>Epischura lacustris</i> -----	3 (9)	T (1)	2 (5)
<i>Eurytemora affinis</i> -----	T (6)	2 (11)	1 (9)
Malacostraca -----	T (2)	12 (20)	6 (11)
<i>Pontoporeia affinis</i> -----	T (2)	12 (20)	6 (11)
Insecta -----	13 (32)	19 (45)	16 (39)
Chironomid larvae -----	13 (29)	16 (42)	14 (36)
<i>Chironomus</i> spp. -----	1 (10)	5 (9)	3 (10)
<i>Cryptochironomus</i> spp. -----	12 (25)	8 (18)	10 (21)
Chordata -----	21 (21)	20 (19)	21 (20)
<i>Alosa pseudoharengus</i> -----	20 (16)	19 (14)	20 (15)
(larvae)			
<i>Alosa pseudoharengus</i> -----	1 (5)	2 (5)	1 (5)
(eggs)			
Unident. digested matter -----	24 (56)	13 (41)	18 (48)
Stomachs Examined -----	100	120	220 ¹

T Less than 0.5%.

¹ Sum of both years.

Seasonal Changes in Food Habits

Zooplankton volume in stomachs increased from 52% in June to 66% in July 1971, and from 18% in May to 68% in July 1972 (Table 2). Values decreased sharply in August and September during both years, while in October 1971, values increased to June levels. High volumes of larval alewives, chironomids, and *Pontoporeia* in August and September were responsible for low zooplankton per cent volumes during August and September in 1971 and 1972. Per cent volumes in 1970 (2) increased from June to September and declined slightly in October. During three months of 1971 (June, July, and Oct.) per cent frequencies of occurrence were 100% while during four months of 1972 (June, July, Aug. and Sept.) values were above 93%.

Cladoceran per cent volume changes in stomachs were similar to those of zooplankton except for October 1971, where volume increased

to July levels. Volumes were below 10% until July. The July peak of 1971 was 52% while that of 1972 was 29%. Per cent volume and per cent frequency of occurrence of cladocera in 1970 (2) generally increased throughout the summer to maxima of 71 and 100, respectively.

TABLE 2. Monthly per cent volume and per cent frequency of occurrence (parenthesis) of stomach contents of alewives collected in Lake Michigan near Michigan City, Indiana, 1971 (above) and 1972 (below), respectively.

Organisms	May	June	July	Aug.	Sept.	Oct.
Zooplankton -----		52 (100)	66 (100)	9 (77)	24 (53)	55 (100)
	18 (70)	58 (97)	68 (93)	22 (96)	10 (94)	
Cladocera -----		1 (23)	52 (100)	8 (68)	7 (47)	50 (100)
	1 (22)	1 (41)	29 (93)	19 (86)	10 (94)	
<i>Bosmina longirostris</i> --		T (8)	12 (100)	T (23)		1 (33)
	T (17)	1 (34)	16 (93)	9 (77)	T (82)	
<i>Euryercus lamellatus</i> .		T (8)	22 (82)			24 (67)
		T (10)	13 (38)	T (4)	T (6)	
Copepoda -----		52 (100)	14 (100)	T (59)	18 (47)	5 (100)
	17 (74)	57 (100)	39 (83)	3 (54)	1 (47)	
Cyclopoida -----		39 (100)	12 (100)	T (46)	2 (47)	5 (100)
	6 (65)	51 (97)	39 (83)	2 (54)	T (47)	
<i>Cyclops bicuspidatus</i> --		39 (100)	12 (100)	T (46)	2 (47)	5 (100)
	6 (65)	50 (97)	39 (83)	2 (54)	T (47)	
Calanoida -----		1 (15)	2 (61)	T (23)	16 (40)	T (17)
	10 (35)	2 (28)	T (7)	1 (27)	T (24)	
<i>Epischura lacustris</i> --				T (9)	15 (40)	T (17)
				T (4)		
<i>Eurytemora affinis</i> ---		1 (15)	T (7)	T (4)		
	10 (30)	2 (14)	T (3)	T (4)		
Malacostraca -----				T (4)		T (17)
		10 (21)	8 (10)	31 (54)	12 (18)	
<i>Pontoporeia affinis</i> ---				T (4)		T (17)
		10 (21)	8 (10)	31 (54)	12 (18)	
Insecta -----		T (8)	2 (18)	62 (100)		T (17)
	55 (100)	12 (45)	1 (10)	26 (68)		
Chironomid larvae -----		T (8)	1 (11)	62 (100)		T (17)
	40 (100)	12 (45)	T (3)	25 (64)		
<i>Chironomus</i> spp. ----			T (2)	4 (41)		
	17 (22)			9 (27)		
<i>Cryptochironomus</i> spp.		T (8)	1 (7)	57 (96)		
	12 (26)	11 (21)		15 (41)		
Chordata -----			4 (11)	5 (9)	68 (13)	29 (50)
		4 (10)	4 (10)	17 (18)	76 (81)	
<i>Alosa pseudoharengus</i> --				5 (9)	68 (13)	29 (50)
(larvae)				17 (18)	76 (81)	
<i>Alosa pseudoharengus</i> --			4 (11)			
(eggs)		4 (10)	4 (10)			
		43 (85)	28 (50)	24 (82)	7 (20)	16 (33)
Unident. digested matter	27 (65)	16 (52)	16 (45)	4 (23)	2 (6)	
Stomachs Examined -----						
1971 -----		13	44	22	15	6
1972 -----	23	29	29	22	17	

T Less than 0.5%.

Bosmina longirostris was an important component of the diet in July 1971, and in both July and August 1972. Maximum abundance in 1972, when plankton samples were taken, occurred in June and July. In 1970 (2), *B. longirostris* reached its maximum per cent volume and per cent frequency of occurrence in alewife stomachs in September.

Eurycercus lamellatus was an important food item only in July and October 1971. The maximum volume of *E. lamellatus* in 1970 (2) occurred in September.

Copepods were important food items in June of each year when they contributed over 50% to the total food volume. Of the remaining months, only July 1972, was above 20% of the volume. Frequency of occurrence was 100% in June, July, and October 1971, and in June 1972, and was never less than 45% in any month of either year. Lowest values occurred in September of both years. Rhodes (2) found copepod per cent volume was maximum in July 1970, and per cent frequency of occurrence was maximum in September 1970.

Cyclops bicuspidatus was the dominant cyclopoid copepod consumed. Cyclopoid copepods were generally more important than calanoid copepods each month of the study with the exceptions of September 1971, and May 1972. *Cyclopoid bicuspidatus* was dominant in June and July of both years. Maximum plankton densities of *C. bicuspidatus* in 1972 also occurred in July. Rhodes (2) also reported a peak in July.

The calanoid copepod, *Eurytemora affinis*, occurred in stomachs between May and August. It comprised 10% of the volume in May, more than in any other month when it was consumed. According to Rhodes (2) maximum volume in 1970 occurred in August, but fish samples were not taken during May 1970. *Epishura lacustris* was the dominant calanoid copepod consumed in September when it comprised 15% of the volume.

The largest per cent volume and per cent frequency of occurrence of *Pontoporeia affinis* in alewife stomachs, 31 and 54%, respectively, occurred in August 1972. *Pontoporeia affinis* was of negligible importance in 1971. Per cent volume during June, July, and September 1972, ranged from 8 to 12%. Rhodes (2) found alewives consumed the largest volume of *P. affinis*, 22%, in October.

Chironomid larvae were significant foods in August 1971, and May and August 1972. Per cent volumes during these months were 62, 40, and 25%, respectively. Per cent frequencies of occurrence were 100, 100, and 64%. In 1970 alewife stomachs, chironomid larvae per cent volume and frequency of occurrence, 25 and 54% respectively, were maximum in June (2).

In 1971, the dominant chironomid larvae consumed was *Cryptochironomus* spp. In August, *Cryptochironomus* composed 57 of the total 62% volume for that month. In May 1972, *Chironomus* predominated at 17% volume. *Cryptochironomus* was dominant in June and August at 11 and 15% volumes, respectively.

Alewife larvae did not appear in stomachs until August. This would be expected since spawning is essentially completed by the end of July. Maximum per cent volume of alewife larvae consumed occurred in September of each year. In 1971, per cent volumes for August, September, and October were 5, 68, and 29%, respectively. In 1972, per cent volumes for August and September were 17 and 76%, respectively. Per cent frequencies of occurrence for 1971 ranged from 18 in August to 81% in September.

Summary

- 1) Zooplankton comprised the major portion of the alewife diet in both years. Per cent volume of plankton and cladocera reached a maximum in July of each year. Copepods were the dominant food item in June.
- 2) Chironomid larvae were a major component of the diet in May 1972, and August of both years. The largest per cent volume of alewife larvae in stomachs occurred in September.

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Growth and Movement of Fish in the Vicinity of a Thermal Discharge

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Abstract

This paper summarizes 2 years of study on the growth and movement of fish in three areas above, next to and below a thermal effluent into the White River at Petersburg, Indiana. The Indianapolis Power and Light Company (IPALCO) electric-generating plant operated a single 220 Megawatt (MW) unit in 1969, which caused an average temperature elevation of less than 1° Fahrenheit. In 1970 a second unit of 420 MW was put into operation which caused an average temperature elevation of 3°F. With both units operating, the Plants normal output is about 640 MW. It has a temperature change of 20°F and a rate of flow of about 675 cubic feet per second. Maximum discharge temperatures reached over 100°F and cooled gradually downstream.

Mark and recapture data showed a majority of the centrarchids to remain in the same areas as originally captured and to move away from the heated water less than towards it. Catch-per-hour electrofishing data also showed the number of centrarchids decreased in the heated water while the number of other species (more thermally tolerant) increased in the heated water.

Using the scale method, age and growth characteristics of 328 longear sunfish (*Lepomis megalotis*), 56 green sunfish (*Lepomis cyanellus*), 361 bluegill (*Lepomis macrochirus*), 489 spotted bass (*Micropterus punctulatus*), 194 white crappie (*Pomoxis annularis*), and 47 black crappie (*Pomoxis nigromaculatus*) were studied. Length-weight relationships were also tabulated for 2,158 gizzard shad (*Dorosoma cepedianum*). All fish were collected from May 1969 to November 1970.

No significant differences could be determined in the growth rates from separate areas, thus the data were combined to be presented as growth dynamics in this area of the White River. A comparison of the growth rates of these seven species with the same species studied in other areas in the Midwest showed that the White River specimens grow neither extremely slow nor extremely fast but rather fit within the range of established growth rates for the region.

In each species studied, the majority of the specimens fit into the II, III and IV-year age classes, with fewer fish in the age classes above IV. Although fewer specimens fit into the age 0 and I-year classes, this was attributed to collecting gear selectivity and not to a reduction in the numbers of these age specimens in the area.

Introduction

From May 1969 to November 1970 a study was conducted to determine the effect of a thermal effluent from the Indianapolis Power and Light Company (IPALCO) electric-generating plant on the growth and movement of fish in the White River near Petersburg, Indiana (3, 5, 16). The Plant operated a single 220 MW unit in 1969 which caused an average temperature elevation of less than 1°F. In 1970 a second unit of 420 MW was put into operation which caused an average temperature elevation of 3°F. With both units operating, the Plant's normal output is about 640 MW. It has a ΔT of 20°F and a rate of flow of about 675 cu ft/sec. This paper presents information related to the growth and movement of various species of fish as related to the heated effluent which reached temperatures over 100°F during the summer months in the discharge area and cooled as it moved downstream.

Description of the Study Area

The study area consisted of three river sections: Section A (above the Plant), Section B (mixing section) and Section C (below the Plant) covering 2,400, 3,200 and 6,700 feet, respectively, and 25, 33 and 69 surface acres, respectively. An additional section designated Relocated Lick Creek (RLC) which is a ditch containing little water except during periods of high river water, was also studied. Sections A, B and C averaged 450 feet wide and were fairly homogeneous with mostly wooded shorelines dotted with fallen trees, overhanging branches and submerged logs. The depth normally ranged from 4 to 14 feet with sluggish midstream currents of 1 to 3 ft/sec. The bottom consists of mud, sand, silt, washed gravel and hard clay. The water level fluctuates about 30 feet during flood conditions and is usually turbid with Secchi disc readings of less than 1 to 2 feet. The White River in this area is typical of midwestern rivers which drain agricultural bottom land. The sections are not identical with respect to depths, currents, bottoms and other habitat requirements of fishes.

Methods

All fish were captured by means of a 600-v d-c, battery-operated electro-fisher. Most of the collecting was done along the shores of each section in water ranging in depth from 6 inches to 4 feet, except in RLC where the entire section was always shocked.

A shocking run was conducted by boat about 10 feet from shore up or downstream at idling speed. Each run was timed and all fish captured were marked with acrylic polymer dye and an accessory fin clip (2) and returned to the mid-point of each section. A particular combination of fin and dye color was sufficient to identify a recaptured fish as to date and section of its original capture. A scale sample was taken from the caudal peduncle of each fish to be used in calculation of age and growth, and all fish were measured to the nearest 0.5 cm and weighed to the nearest gram for calculation of condition factors. All age and growth analyses were performed by standard fisheries techniques as described in detail by Ricker (18) and Benda (3).

Results and Discussion

As a group, the centrarchids studied were shown to remain for extended periods in the section of the river where captured and released. Less movement was shown away from the heated water than towards it. Table 1 shows the number of fish marked and recaptured in each section in each year and where the fish were recaptured in relation to where they were first captured. The majority of the fish were recaptured in the same section they were originally captured and marked indicating restricted movements of centrarchids such as Gerking (8, 9) found. The spotted bass, bluegill and white crappie showed more movement toward the heated water than the longear sunfish which showed greater movement away from the heated water. It was determined that as temperatures increased in the

discharge area to over 100°F all species abandoned this area as their tolerances were reached.

TABLE 1. Number of fish marked and recaptured and the per cent of recaptured fish which were retaken in the same section (PRS), retaken moving toward the heated section (PRT), and retaken moving away from the heated section (PRA) for both years.

Species and Section	1969		1969-70			1970	
	Number Marked	Number Recapt.	PRS	% PRT	PRA	Number Marked	Number Recapt.
Longear sunfish							
Section A -----	61	19	98	2		70	8
Section B -----	103	45	87		13	53	5
Section C -----	95	6	71		29	56	1
Spotted bass							
Section A -----	76	21	94	6		126	21
Section B -----	75	36	82		18	148	45
Section C -----	57	1	69	25	6	107	5
Bluegill							
Section A -----	81	10	70	30		141	11
Section B -----	48	7	81		29	77	18
Section C -----	73	2	100			70	6
White crappie							
Section A -----	48	2	75	25		64	5
Section B -----	32	1	100			33	3
Section C -----	47	2	100			12	1
¹ Other species -----	790	12	72	17	11	1604	23

¹ Includes carp, carpsucker species, gizzard shad, white bass, largemouth bass, and shortnose gar.

Electrofishing catch data based on time in Table 2 shows that Section B, except for June 1970, had a higher rate for fish captured per hour than Section A and except for September 1970 than Section C. Gammon (7) found that although there were losses in numbers of certain species of fish (centrarchids), other more thermally-tolerant species (carp, *Cyprinus carpio*, longnose gar, *Lepisosteus osseus*, shortnose gar, *Lepisosteus platostomus*, carpsuckers, *Carpionides* sp., etc.) moved into the heated area and the standing crops either remained the same or increased.

Fish of all species left the river during flood conditions and sought the quieter waters of Relocated Lick Creek (RLC). This can be seen in Table 2 when collecting was done in RLC. This was evidenced only during flood conditions especially in June 1970 when 172.6 fish per hour were collected. Overall the movement of fish was temperature dependent and as temperatures increased and tolerances were exceeded, all fish eventually abandoned the heated water and moved into cooler water areas.

Table 3 shows the body length-magnified scale radius relationship for six species of fish, while Table 4 shows the back calculated mean total lengths for the 1,475 fish by species. A comparison of the growth rates of the six species of centrarchids studied in the White River with the same species studied in other areas of the Midwest shows

that the White River species grows neither extremely slow nor extremely fast, but rather falls within the range of established growth rates (1, 4, 6, 10 thru 15, 17, 19).

TABLE 2. *Catch of fish per hour by electro-fishing in Sections A, B, C, and RLC during June, July, August, September, October and November for 1969 and 1970.*

Month-Year	Section	Total Fish	Total Shocking Time	Ave. No. Fish/Hour
1969				
August -----	A	245	10.7	23.6
	B	348	13.2	26.1
	RLC	188	3.6	54.8
September -----	A	380	12.8	20.2
	B	478	12.8	33.0
October -----	C	516	7.7	67.4
	RLC	30	0.4	71.1
November -----	A	28	1.5	18.6
	B	58	1.7	33.6
1970				
June -----	A	577	13.6	42.1
	B	416	11.3	36.7
	RLC	214	1.5	172.6
July -----	A	187	5.5	33.3
	B	309	6.1	50.6
	C	202	4.0	50.5
August -----	A	384	8.9	43.1
	B	445	9.4	47.3
September -----	A	60	2.4	25.0
	B	50	1.5	33.3
	C	339	10.1	35.3

In each species studied the majority of the fish fit into the II, III and IV-year age classes with fewer fish in the age classes above these, which compares favorably to the other above-mentioned studies. The lack of numerous age class 0 and I fish was attributed to collecting gear selectivity rather than to lack of fish in these groups.

TABLE 3. *The relationship between magnified scale radius (SC) in mm and total length (TL) in mm: (CF indicates the correction factor); (r indicates the regression coefficient).*

Species	Number	Body-scale Relationship	CF	r
Longear sunfish -----	328	SC = -2.0155 + 0.3536 TL	-11.2939 ¹	.925
Spotted bass -----	489	SC = -1.8768 + 0.2609 TL	7.1251	.971
White crappie -----	194	SC = -2.6827 + 0.3223 TL	8.2908	.945
Bluegill -----	361	SC = -2.5202 + 0.3792 TL	6.5004	.951
Black crappie -----	47	SC = 5.5445 + 0.2925 TL	-21.5293 ¹	.912
Green sunfish -----	56	SC = 0.807 + 0.2882 TL	-4.4811 ¹	.845

¹ Indicates a linear intercept of 0.00 was assumed due to the regression line intercept being a negative value.

Table 5 shows the mean condition factors for 1969 and 1970 divided up into length intervals for four of the species studied. Mean condition

factors for 1970 for longear sunfish, bluegill, spotted bass and white crappie showed the fish to be in better condition (heavier at most length intervals) than those collected in 1969. This was attributed to increased silt in the river due to more frequent flood conditions in 1969 than 1970 thus limiting feeding time for these piscivorous fish.

TABLE 4. *Calculated mean total length, mean weight, and total length increments of fish from the White River.*

Age Class	Number of Fish	Mean Total Length (mm)	Total Length Increment (mm)	Mean Weight (gms)
328 Longear Sunfish				
0	16	61.3	61.3	28.9
I	33	81.9	20.6	47.6
II	51	109.2	27.3	87.2
III	188	128.2	19.0	94.5
IV	25	140.2	12.3	102.3
V	13	148.8	8.3	123.6
VI	2	152.5	3.4	142.7
489 Spotted Bass				
0	137	75.5	75.5	33.3
I	93	102.1	26.6	38.7
II	48	153.1	51.0	66.3
III	139	194.5	41.4	113.8
IV	46	245.5	51.0	178.1
V	18	263.1	17.6	231.3
VI	8	270.4	7.3	351.3
194 White Crappie				
0	1	68.5	68.5	22.4
I	29	101.6	33.1	33.9
II	78	159.1	57.5	52.9
III	73	201.3	42.2	102.8
IV	8	244.4	43.1	165.3
V	4	250.0	5.6	262.5
361 Bluegill				
0	23	62.0	62.0	23.7
I	62	77.2	15.2	35.8
II	106	106.0	28.8	47.6
III	142	134.5	28.5	75.3
IV	16	168.3	33.8	108.5
V	7	182.1	13.8	148.3
VI	5	186.0	3.9	186.7
47 Black Crappie				
I	6	70.2	70.2	20.2
II	21	149.5	79.3	53.6
III	14	178.6	29.1	68.6
IV	6	188.9	10.3	136.2
56 Green Sunfish				
0	8	72.4	72.4	25.5
I	33	77.3	4.9	34.6
II	14	95.8	18.5	44.3
III	1	135.6	40.0	61.7

TABLE 5. Mean condition factors for length groups of *Centrarchids* for 1969 and 1970.

Length Group (mm)	Longear Sunfish		Bluegill		Spotted Bass		White Crappie	
	1969	1970	1969	1970	1969	1970	1969	1970
55 -----	—	—	—	—	—	8.1	—	—
75 -----	5.1	6.6	—	—	—	—	—	—
85 -----	3.5	5.5	3.5	5.6	3.5	5.4	—	—
95 -----	3.4	5.0	3.0	4.3	—	—	—	—
105 -----	3.0	3.9	2.8	3.9	—	—	—	—
115 -----	3.1	3.8	2.7	3.2	2.2	2.9	2.1	1.5
125 -----	2.9	3.6	2.2	3.3	—	—	—	—
135 -----	2.9	3.5	2.7	3.0	—	—	—	—
145 -----	2.8	3.1	2.2	3.0	1.5	2.4	1.4	1.7
155 -----	2.8	3.2	2.5	2.9	—	—	—	—
165 -----	2.6	3.3	2.2	2.8	—	—	—	—
175 -----	—	—	2.5	2.8	1.3	1.9	1.4	1.5
185 -----	—	—	—	2.9	—	—	—	—
205 -----	—	—	—	—	1.4	1.7	1.4	1.6
235 -----	—	—	—	—	1.3	1.5	1.4	1.5
265 -----	—	—	—	—	1.3	1.4	1.4	1.5
295 -----	—	—	—	—	1.3	1.3	—	—

A comparison of the length-weight distributions of 2,158 gizzard shad collected with those from the study by Lagler and Applegate (4) showed the majority of the fish were in age classes II, III, IV and V, based on their length intervals. The comparison of weight-length data showed most of the fish were in weight groups below 260 g.

Overall the seven species of fish studied displayed average growth rates when compared to other areas indicating normal growth of these fish in this section of the White River. Their growth does not seem to be affected by the thermal discharge either beneficially or detrimentally.

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ENGINEERING

Chairman: THOMAS J. HARRICK, Department of Aeronautical-Astronautical Engineering, Purdue University, Lafayette, Indiana 47907

J. W. DELLEUR, School of Civil Engineering, Purdue University, Lafayette, Indiana 47907, was elected Chairman for 1974

ABSTRACTS

The Seismicity of Indiana and Civil Engineering Structures. WILLIAM D. KOVACS, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.—The earthquake history of the Indiana Area is reviewed to evaluate potential damage to transportation and other civil engineering structures. This review was made because of the increased seismic risk associated with the Indiana area as delineated by the Revised Seismic Risk Map published by the National Oceanographic and Atmospheric Administration (NOAA) (formerly the U.S. Coast & Geodetic Survey).

Based on the review of historical earthquakes and known and inferred faults in the Indiana Area, it is concluded that the Southwest quarter of Indiana has been and will continue to be subject to violent shaking. Records indicate the Southwest portion has experienced Intensities (the effect of an earthquake on man's structures) of VII through IX at the extreme southwest tip of the state. Intensity VII is considered to be the threshold of structural damage.

Two sources of future earthquakes will cause damage in Indiana. A magnitude 7 to $7\frac{1}{4}$ earthquake can be expected to occur in the future with its epicenter along the New Madrid (Missouri) fault system. Perhaps more important is that the Wabash River Fault System is expected to release a magnitude 6 to $6\frac{1}{4}$ earthquake within the 1970's. The 1971 San Fernando, California, earthquake magnitude was 6.5 and the total property loss may approach 1 billion dollars.

It is suggested that the information contained herein be used in a study that will enable seismic design provisions to be incorporated into an Indiana Building Code for highway structures and buildings. Presently there are no such provisions.

The Relationship between Ground Water Levels, Precipitation, and River Stages. JOHN A. SPOONER, A. RAMACHANDRA RAO, and BATHALA T. CHENCHAYYA, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.—Groundwater level data observed at three locations near the river in the Kankakee River basin aquifer system, the related precipitation and river stage data were analyzed to determine relationships existing among them. Some preliminary results of this analysis are presented herein. Groundwater level fluctuations and some anomalies observed in these fluctuations were analyzed by utiliz-

ing the geological and hydraulic characteristics of the aquifers. A regression analysis of the groundwater levels, precipitation data, and river stages was conducted to obtain a quantitative relationship between them. Finally, the transfer function relating the groundwater level fluctuations and river stages has been identified and verified. It is hoped that the final results of this study will help in a better understanding of groundwater levels as they affect agriculture within the basin.

Estimating 1973 Weekly Energy Use for Indiana Corn Drying by Simulation. ROBERT M. PEART, Department of Agricultural Engineering, JAMES E. NEWMAN, Department of Agronomy, SAMUEL PARSONS, Extension Agricultural Engineer, and WALTER L. STIRM, Advisory Agriculture Meteorologist, Purdue University, West Lafayette, Indiana 47907.—A computer program was developed to predict the weekly demand for LP gas and natural gas for corn drying. On September 3, a month before normal harvest begins, the program predicted a total need for 47 million gallons of LP fuel and 1.3 billion cubic feet of natural gas for drying Indiana's corn crop. This was based on 1973 weather to September 3, normal harvest weather, an average of 107 bushels per acre, and 80% of the crop requiring drying. The program took into account the actual weather and planting dates, the harvest capacity, average harvest weather, and corn drying patterns in each of the 9 crop reporting districts of the state. Results for each district gave the predicted demand for LP and natural gas for corn drying for each week from early September through December.

These estimates were possible because of data accumulated by the cooperative Purdue-USDA Statistical Reporting Service, the State Climatologist, NOAA Agricultural Weather Service, seed company data, and past research in the Agronomy and Agricultural Engineering Departments. The computer program was developed during the summer of 1973, but it would not have been possible without the tremendous reservoir of data and research that have been accumulated over many years.

A Mathematical Modeling of Ground Water Contaminant Decay.¹ G. AGUIRRE and J. E. LINDELL, Department of Mathematics, University of Notre Dame, Notre Dame, Indiana 46556.—Several researchers have reported noticeable impairment of ground water quality due to contamination of ground water with leachates emanating from sanitary landfills. These contaminants arise from the decomposition of organic matter in the refuse, dissolution and corrosion of metal and metal-containing wastes, and acidic leaching of water-soluble species from soil minerals in and below the landfill. The most significant of these pollutants are organic carbonaceous materials (as measured by the BOD or COD of the water); dissolved minerals, primarily calcium, magnesium, and iron; reduced chemical species, such as ammonia,

¹ This work was supported by the Office of Water Resources Research, U.S. Department of the Interior under Research Grant No. 14-31-001-3705.

sulfide and methane; total dissolved solids (or conductivity); and increased acidity (mostly as CO_2) with a concomitant depression of pH.

As the ground water contaminants are transported downstream from the landfill site with the ground water flow, concentrations are reduced via interaction with soil media and by dispersion mechanisms. The rate of decline of contaminant concentration with distance downstream from the landfill site is dependent on hydrogeologic characteristics of the area.

The purpose of this paper is to discuss a hydrogeologic investigation of a sanitary landfill in St. Joseph County, Indiana, and to relate it to the development of a mathematical model of the concentration decay of ground water contaminants. The significant hydrogeologic parameters under investigation are the ground water surface profile, soil permeability and dispersion coefficient. The significant water quality parameters used in the modeling are alkalinity, hardness, calcium and conductivity. A network of wells was placed in the area downstream from the landfill for the purpose of monitoring water quality and determining the water surface profile. Data from this network was used to verify the dispersion model. The model is used to predict contaminant concentrations and hence water quality recovery rate downstream from the sanitary landfill.

Biomedical Engineering and Health Care Delivery. PAUL E. STANLEY, Coordinator, Biomedical Engineering Center, Purdue University, West Lafayette, Indiana 47907.—Health care delivery has been of interest to mankind almost as long as his recorded history. For more than 200 years, physics and, more recently, engineering, has contributed to the practice of medicine providing a better understanding of many physiological functions. Since early in this century, and especially since World War II, great strides have been made in the application of electrical and electronic devices to health care delivery. This paper delineates some of these developments and reviews many of the interdisciplinary biomedical engineering research and development activities now in process at Purdue University.

Geomorphologic Characteristics of Fourteen Indiana Watersheds Obtained from a Computer Data Bank of Stream Networks

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Abstract

Twenty-eight geomorphologic properties were obtained for each of 14 Indiana watersheds. These properties are based on Strahler's stream ordering system and on Shreve's stream link magnitude system. The laws of the stream numbers and of the stream lengths, in general, were found to be valid. The bifurcation ratio has a nearly constant value of about 4.5, almost equal to the ideal network value. The mean first-order stream length ranges from 0.08 to 0.13 miles, a comparatively low value due to the detail of the maps used. The drainage area is strongly correlated to the stream length and is inversely related to the watershed slope. Weaker correlations exist between the drainage area and the drainage density and between the drainage area and the texture ratio.

Basic Geomorphologic Parameters

There are two classifications of stream networks which are widely used. The Strahler ordering system assigns the order one to every unbranched fingertip tributary segment. Two first-order streams unite to form a second-order segment. A third-order segment is formed by junction of two second-order streams, but may be joined by additional first- or second-order segments. If two unequal channels unite to form a segment its assigned order is the same as the larger order of the two upstream segments. In Shreve's link magnitude system all exterior links are assigned the magnitude of one. The junction of any two links increases the magnitude of the resulting downstream link, the magnitude of which is the sum of the magnitudes of the two upstream links.

Based on these two systems, numerous drainage basin characteristic parameters were derived. The interrelationships between these parameters and other basin characteristics calculated directly from the stream network data form the structure shown schematically in Figure 1. This structure consists of three major parts based on the Strahler stream ordering system, the Shreve link-magnitude system and the direct measurements from drainage basins, respectively. The major function of Strahler's stream ordering system is the assignment of an order to each stream segment. The order of a basin, U_B , is defined as the order of the largest segment which it contains.

The basic function of Shreve's link-magnitude system is the assignment of a magnitude to each link. The magnitude of a basin, M_B , is defined as the magnitude of the largest link which it contains.

In the third part, direct measurements from basin maps are used to estimate the geomorphologic parameters. Four parameters describe the most important characteristics of basins. They are: the drainage

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area, the basin perimeter, the basin length and the basin slope. The basin length is defined as the maximum straight line distance between a point on the basin perimeter and the stream mouth. The basin slope is defined as the total relief, or the difference between the highest contour and the elevation of the basin mouth, divided by the main stream length. The primary basin parameters are the number of streams of a given order, N_u , the length of a stream of a given order, L_u , the bifurcation ratio R_B , the number of links of a given magnitude N_m and the link length of a given magnitude.

The secondary basin parameters were derived from the three major parts of the geomorphic parameter structure. They are the texture

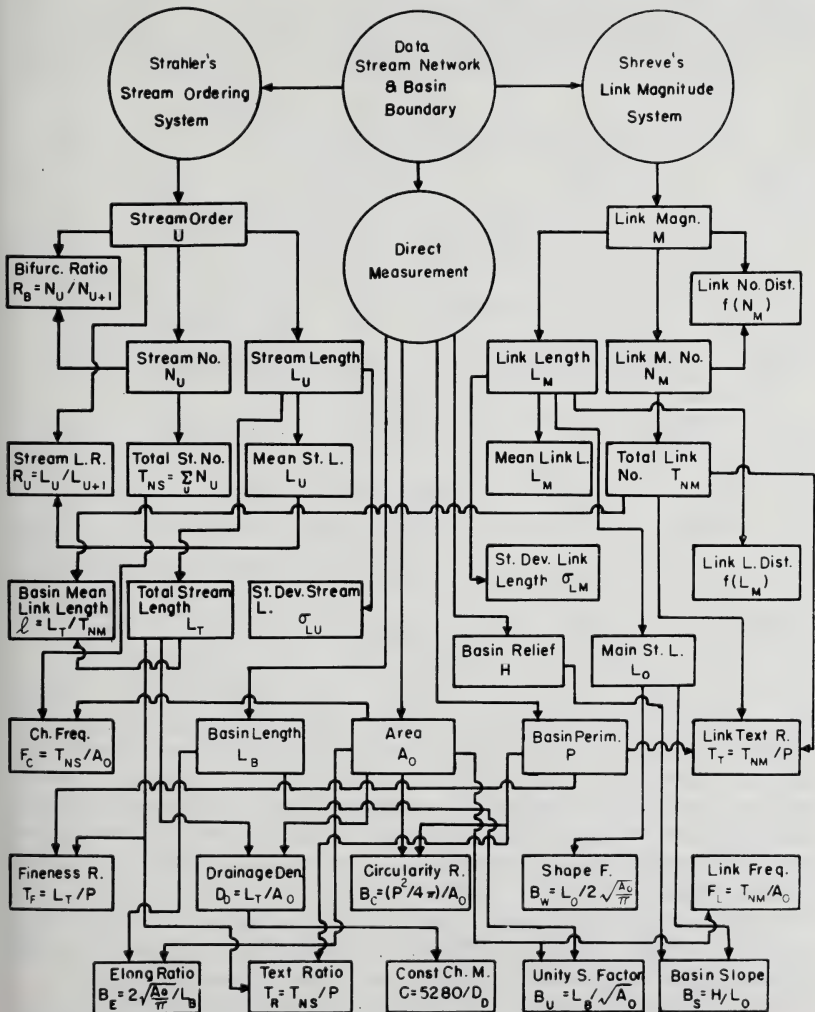


FIGURE 1. Interrelated scheme of geomorphologic parameters.

ratio, the link-texture ratio, the fineness ratio, the drainage density, the constant of channel maintenance, the channel frequency, the channel link frequency, the circularity ratio, the elongation ratio, the watershed shape ratio, and the unity shape factor. Working definitions of the primary and secondary basin parameters were given by Coffman *et al.* (1) and are shown schematically in Figure 1.

Data Acquisition

The coordinates of stream junctions and sources and of the boundaries of the 14 Indiana watersheds listed in Table 1 with areas varying between 3 and 220 square miles were obtained from the Purdue University Atlas of County Drainage Maps (2). These coordinates were stored on magnetic tapes (3). These data were processed using the W.A.T.E.R. System Computer Program for Stream Network Analysis (1).

TABLE 1. *Watersheds for geomorphologic analysis.*

Water- shed No.	Watershed Name	Water- shed No.	Watershed Name
1	Lawrence Cr. at Ft. Benjamin Harrison	24	Buck Cr. at Muncie
2	Bear Cr. near Trevlac	35	Salamonie River at Portland
3	Bean Blossom Cr. at Bean Blossom	37	Bice Ditch near South Marion
10	Big Blue River at Carthage	39	Little Cicero Cr. near Arcadia
16	Hinkle Cr. near Cicero	42	Wildcat Cr. near Jerome
19	Brush Cr. near Nebraska	43	Slough Cr. near Collegeville
22	Cicero Cr. at Noblesville	44	Little Indian Cr. near Royal Center

Analysis of Geomorphologic Data

Horton proposed that the stream numbers and the stream lengths vary with the stream orders in a geometric progression. Accordingly, the plot of the data on semi-logarithmic paper, should result in an approximately straight line. The stream numbers and the mean stream lengths are plotted versus the stream orders for 12 basins as shown in Figure 2. The plots are approximately straight lines with the exception of the stream length plots of Bean Blossom Creek (WS3), Little Cicero Creek (WS39), Wildcat Creek (WS42), Slough Creek (WS43) and Little Indian Creek (WS44) which are of the "incomplete" type networks. These incomplete networks contained only two streams of the second highest order, the minimum number to form the highest order streams which, in turn, were very short. In general, the law of the stream numbers is obeyed much more strongly than that of the stream lengths.

The average first order stream length ranges from 0.08 to 0.20 miles in Indiana small watersheds. These small values are due to the great detail with which the drainage maps were drawn.

The bifurcation ratio, R_b , provides some measure of a stream segment's tendency to divide. Coates (4) measured some basins in south-

ern Indiana and found bifurcation ratios for first-order to second-order streams ranging from 4.0 to 5.1. Shreve (5) reported that: "For a given number of first-order streams in network, the most probable network is that which makes the geometric mean bifurcation ratio close to 4." The distributions of the bifurcation ratios for 1st to 2nd, 2nd to 3rd and 3rd to 4th order in 13 basins ranged from 2.8 to 7.0. The average bifurcation ratios were almost constant and equal to about 4.5. This shows that Indiana stream networks have a slightly higher bifurcation ratio than those of topologically random networks which might indicate that minor geological controls occur in this area. The general trend indicates that the mean bifurcation ratio decreases as the stream order increases and that the standard deviations increase as the stream order increases.

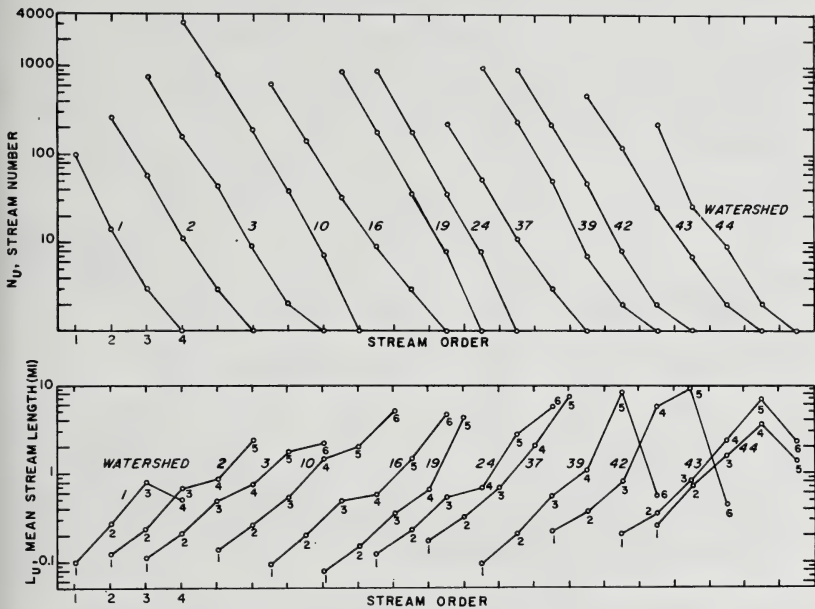


FIGURE 2. Laws of stream numbers and stream lengths.

Shreve (5), in his study of the "Law of Stream Lengths", stated that the average length of streams increases with order as a geometric series with ratio 2. Thus the stream length ratio should be approximately equal to 2. This was found to be indeed true for the lower order streams but both the bifurcation ratio and the stream length ratio of the highest order (i.e., 5-6 order) do not follow the trend, because they contain "incomplete segments". The mean stream length tends to increase slowly as the stream order increases. At the same time, the standard deviation increases as the stream order increases.

Shreve (6) reported that the discrete probability density function $V(M)$ of randomly drawing a link of magnitude M in an infinite topologically random channel network is:

$$V(M) = \frac{2^{-(2M-1)}}{2M-1} \binom{2M-1}{M} \quad [1]$$

and that the differences between the probabilities for infinite and finite topologically random networks are very small when M_B is larger than 200. The basin magnitudes of the Indiana watersheds studied ranged from 97 to 3,066 with an average of 900 and with only two basins having magnitudes less than 200. Figure 3 shows the function $V(M)$ and the observed frequency distribution for six basins. The link number probability density distribution function is a discrete function but for easier visualization link magnitudes were connected by lines. The streams with magnitudes greater than 10 were neglected because they represent a very small portion of the total population. The departures from the topologically random network magnitude frequency were not too large for most of the networks. The differences show the lower magnitudes have lower frequencies than those of random networks. This property causes the bifurcation ratio to increase at low Strahler stream order. This conclusion coincides with the results from bifurcation ratios.

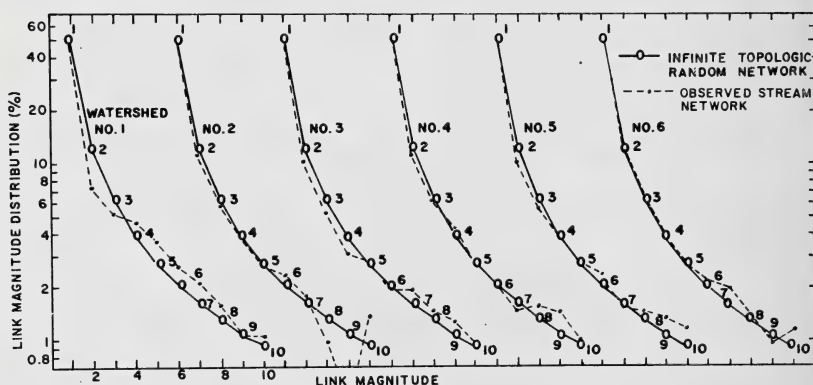


FIGURE 3. Link number distribution.

Means and standard deviations of link lengths are shown in Figure 4 for some of the watersheds. The mean link length varies with the link magnitude. For most of the basins the exterior links have larger mean link lengths than the interior links. The means of interior links show a general trend to decrease as the link magnitudes increase in most basins. The standard deviations vary little with the link magnitudes. This information illustrates the conclusion that the mean exterior links are larger than the mean interior links.

Summary Table of Watershed Characteristics

The summary of watershed characteristics of these 14 basins is given in Table 2. From this table, a few relationships between watershed characteristics may be obtained.

1) Relationship between drainage areas and mean stream lengths.

The data were plotted in log-log scales, a least square fit gave the regression equation:

$$L_o = 1.64 A_o^{0.55} \quad [2]$$

Where L_o = main stream length, in miles, and A_o = drainage area, in square miles.

- 2) Smaller watersheds tend to have steeper slopes.
- 3) Watersheds with steeper slopes have higher drainage densities.
- 4) The drainage density tends to increase as the texture ratio increases.
- 5) There is no consistent relationship between the elongation ratio and the drainage area.

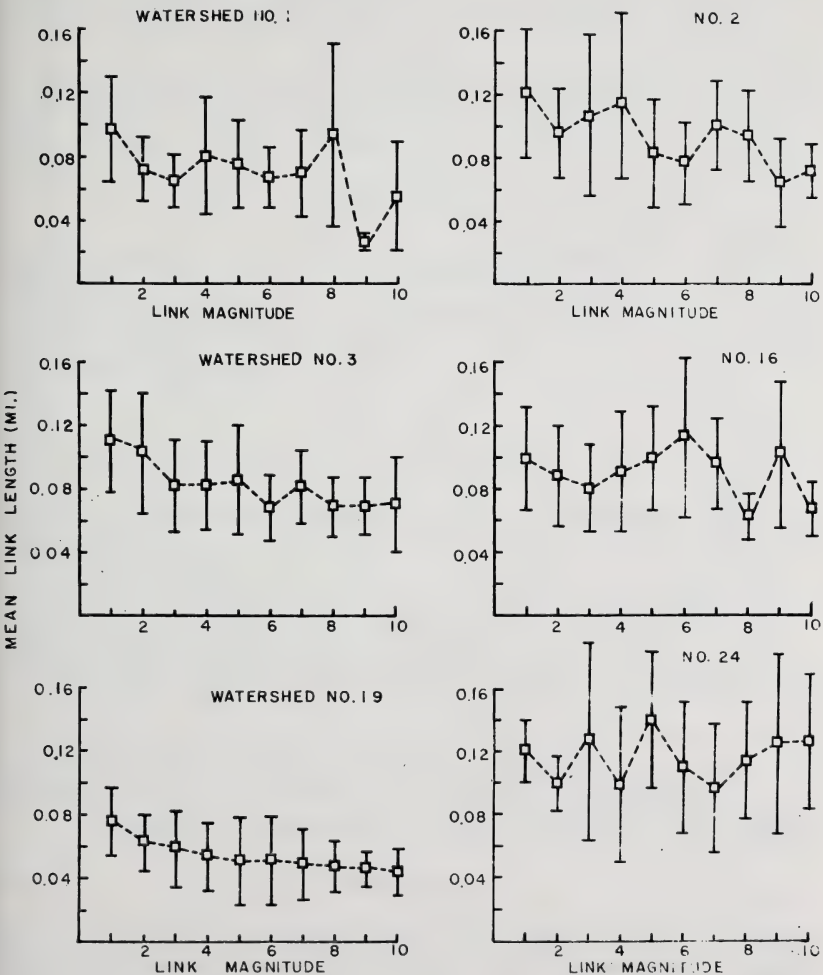


FIGURE 4. Means and standard deviations of link lengths.

TABLE 2. *Geomorphologic characteristics of 14 Indiana watersheds.*

Item	Symbol	Unit	WS 1	WS 2	WS 3	WS 10	WS 16	WS 19	WS 22	WS 24	WS 25	WS 37	WS 39	WS 42	WS 43	WS 44
1 Area	A_0	sq.miles	2.64	5.80	13.4	169.72	18.2	10.31	205.738	33.84	80.55	22.03	42.06	138.2	78.85	33.43
2 Basin perimeter	P	miles	7.42	11.39	18.7	71.94	19.4	18.27	68.12	33.32	40.27	25.31	36.07	68.45	50.42	26.31
3 Basin length	L_B	miles	2.170	3.66	5.22	26.39	4.83	6.63	18.40	9.72	12.03	7.38	9.68	16.68	11.52	8.82
4 Relative relief	H	feet	120.9	310.0	373.6	240.67	110.0	207.8	200.	45.3	182.4	81.7	110.0	80.0	95.3	77.3
5 Basin order	U_B	No	4	5	6	6	6	6	6	6	7	5	6	6	6	6
6 Total No. of seg.	T_{NS}	No	115	332	990	4113	815	1119	3928	1091	2820	294	1304	1216	647	167
7 Basin magn.	M_B	No	97	259	785	3066	624	894	3066	817	2159	226	1003	933	490	129
8 Total No. of link	T_{LM}	No	193	517	1569	6138	1247	1787	631	1633	4282	451	2005	1865	979	257
9 Total stream length	L_T	miles	16.15	57.03	149.9	809.66	120.6	116.7	885.722	192.6	469.00	75.40	195.4	386.0	196.6	72.53
10 Main st. length	L_0	miles	2.30	4.17	7.2	29.75	9.8	7.5	42.0	12.5	17.0	11.17	15.75	23.0	15.5	10.45
11 Azimuth of basin length		degree	28.34	205.72	212.9	225.23	86.9	231.48	156.04	280.2	291.0	3.34	76.51	58.41	273.08	263.94
12 Texture ratio	T_R	l/mile	15.49	29.14	52.9	42.62	41.9	61.23	12.771	32.73	70.03	11.61	36.07	17.76	12.83	6.35
13 Link Texture ratio	T_T	l/mile	25.99	45.38	83.8	85.32	64.2	97.77	19.304	49.00	106.33	17.82	55.57	27.24	19.41	9.77
14 Drainage dens.	D_D	mi/sq.mi.	6.10	9.8	11.8	4.88	6.62	11.31	4.305	5.69	5.82	3.42	4.64	2.79	2.49	2.17
15 Const. channel maintenance	C	sq.ft/ft	865.14	537.8	472.12	1219.47	797.3	466.5	1226.5	927.9	906.57	1542.4	1136.6	1890.5	2116.9	2433.6
16 Channel freq.	F_C	l/sq.mi.	43.47	57.15	73.86	21.99	44.7	108.5	19.092	32.23	35.01	13.34	30.9	8.79	8.20	4.99
17 Link freq.	F_L	l/sq.mi.	72.95	86.99	117.06	32.82	68.4	173.3	29.800	48.24	53.16	20.47	47.6	13.49	12.41	7.68
18 Area with basin perimeter	$\frac{P^2}{4\pi}$	sq. mi.	4.38	10.33	27.8	411.92	30.02	25.6	369.286	88.37	129.04	50.97	103.6	372.9	202.34	55.06
19 Dia. of circle	$\sqrt{A_0/\pi}$	mile	1.84	2.72	4.13	14.70	4.81	3.62	16.185	6.56	10.12	5.29	7.32	13.2	10.02	6.52
20 Basin circularity	B_C	No	0.603	0.562	0.48	0.412	0.61	0.38	.957	0.382	0.624	0.432	0.406	0.371	0.389	0.607
21 Elongation ratio	B_E	No	0.846	0.742	0.79	0.557	0.99	0.54	.879	0.675	0.839	0.717	0.755	0.795	0.870	0.739
22 Watershed shape factor	B_W	No	1.25	1.53	1.74	2.024	2.04	2.07	2.593	1.01	1.68	2.11	2.15	1.74	1.55	1.60
23 Unity shape factor	B_U	No	1.334	1.52	1.43	2.026	1.13	2.06	1.283	1.67	1.343	1.57	1.493	1.42	1.29	1.52
24 Basin Mean link length	L	miles	0.0836	0.1103	0.0955	0.1319	0.0967	0.0653	0.140	0.1179	0.1095	0.1671	0.0976	0.2069	0.2008	0.2822
25 Basin slope	B_S	ft/mi	52.1	44.7	22.1	8.07	8.01	26.4	4.762	7.39	10.73	7.31	6.98	3.47	6.10	7.39
26 Link drainage width fact*	K	No	1.95	0.925	0.887	1.748	1.561	1.353	1.608	1.490	1.581	1.748	2.211	1.732	1.999	1.632
27 Link drainage width fact**	K	No	1.96	0.926	0.841	1.751	1.561	1.354	1.608	1.489	1.569	1.750	2.210	1.733	2.001	1.631
28 Channel drainage width fact	K_S	No	1.168	0.595	0.530	1.172	1.019	0.848	1.030	0.995	1.033	1.14	1.43	1.12	1.32	1.05

* $1/(L_0)$ ** F_L/D_0^2

Shreve (6) reported two important parameters relating the linear and area dimensions: the basin mean link length, l , and the drainage width factor, K . The area A_0 of the basin may be written:

$$A_0 = Kl^2(2M_B - 1) \quad [3]$$

where Kl is the average width which the stream link can cover and M_B is the magnitude of the basin and K is the ratio of the average width to basin average link length. The l values ranged from 0.084 to

0.28 miles and the K values ranged from 0.887 to 1.99. The drainage density D_D may be expressed as $D_D = 1/Kl$.

The identification of l and K values can be done as follows: l can be expressed as $l = L_T/T_{MN}$ where L_T and T_{MN} are the total stream length and the total number of links, respectively. The K value can be obtained in two ways. First, it can be obtained from the relationship between the basin mean link length, l , and the drainage density D_D . A plot of $1/l$ versus D_D showed, for drainage density below 8 miles per square mile, a K value of approximately 5/3. The other way to identify the K value is based on the link frequency, F_L . The link drainage factor width can be expressed as $K = F_L/D_D^2$. The plot of F_L versus D_D^2 yielded an estimated value of about 5/3. Similarly, for Strahler's ordering system, the channel drainage width factor can be expressed as $K_s = F_c/D_D^2$, where F_c is the channel frequency.

One of the most important applications of the geomorphologic parameters is in the regionalization of hydrologic models for runoff prediction. In this type of analysis correlation equations are developed between hydrologic and geomorphologic parameters.

Acknowledgment

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Application of Some Statistical Tests to Investigate the Urban Rainfall Characteristics

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Abstract

This study reports statistical analyses of the annual rainfall data from urban and surrounding rural areas. The Rank, Median, Mann-Whitney-U, Run and U-tests of significance were used. Annual rainfall data from stations in Indiana and Oklahoma were analyzed. Results indicate that rainfall characteristics of areas adjacent to large metropolitan areas are significantly different from those of surrounding rural areas.

Introduction

Cities have different climates than the surrounding countryside. The difference results from the effects of several interacting variables such as temperature, amounts of water vapor and precipitation, etc. The rainfall in urban as well as adjacent areas is affected by factors such as increased particulation and convection which are essentially due to the presence of these urban areas.

Previous studies (we have selected only a few from the vast literature available on inadvertent weather and precipitation modification by urbanization (2, 4, 5)) have established clearly that relatively significant micro and meso scale changes in weather occur in and near urban areas. The effect of urbanization and industrialization on rainfall characteristics has been investigated by using several methods such as analysis of rainfall records (3), runoff data (9), etc. The statistical analysis of the effects of urban-industrial effects on rainfall, however, has not received much attention. Only a few studies (7) of the effects of urbanization on rainfall appear to have been conducted so far by using statistical methods. Consequently, statistical analyses of the changes brought about by the urbanization on the rainfall characteristics were undertaken. The present paper deals with a part of the preliminary results obtained by the study.

The annual precipitation data were used in the study. Data from two locations in Indiana and in Oklahoma were selected for the study (Fig. 1). The LaPorte, Indiana, area has been shown to receive consistently higher rainfall than the surrounding areas. This phenomenon was called the "LaPorte Anomaly", by Changnon (3) and was attributed to the effects of Chicago-Gary area. The rainfall at and near Tulsa, Oklahoma, was shown by Landsberg (10) to increase with increasing urbanization in Tulsa. Consequently, these two areas were selected for further investigation.

The nature of the raw data plays a significant role in the statistical analysis of data. Main sources of error are, changes in raingage location, changes in methods of observation (human *vs.* automatic), etc. Some of these aspects of the raw data have created considerable con-

controversy (9), *mainly* in the discussion of LaPorte Anomaly. Some of these aspects are discussed in a forthcoming report and are not presently included for lack of space. However, even if we make the rainfall values in the affected period 10% smaller than the reported values for LaPorte, the conclusions presented herein are still valid.

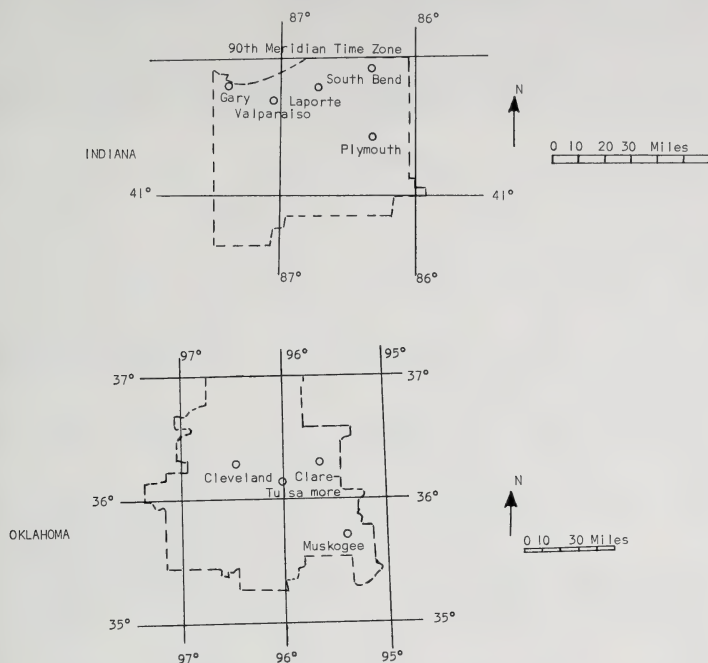


FIGURE 1. Locations of stations.

The annual and mean rainfall at a few stations near LaPorte, Indiana, and Tulsa, Oklahoma, are shown in Figure 2. The mean annual rainfall at the Indiana and Oklahoma stations were shown to change at 1929 and 1931, respectively, by using double mass curve and other techniques. For the data from LaPorte and South Bend, the mean annual rainfall *increased* at about 1929, with the mean showing a larger increase for the data from LaPorte than for the data from South Bend. For the data from Oklahoma, the mean annual rainfall *decreased* at Tulsa and Claremore starting from 1931. In the present paper the period before 1929 and 1931, respectively, for Indiana and Oklahoma, is referred to as the *unaffected* period and the period after is called the *affected* period. The mean and standard deviation of data from the affected and the unaffected periods and the percentage change in mean values are also shown in Figure 2.

From the data presented in Figure 2, it is clear that the mean values of annual rainfall have increased for stations such as LaPorte and South Bend, Indiana, and have decreased for Tulsa, Oklahoma. The main objective of the present paper is to test whether these changes are

statistically significant and not to correlate the rainfall with urbanization indicators. The statistical tests, then, must indicate whether the changes in the rainfall characteristics observed at stations such as La Porte and Tulsa are significant. If these changes in means, medians, etc., of the data from the affected and unaffected periods are significant, then they *may be* attributed to the effects of urbanization. We would like to emphasize, however, that the investigation of the effects of urbanization must not only be statistical but also be reinforced by studies of the "Metromex" type (6). The data on the urbanization of the Chicago-Gary area, and Tulsa, may be found among the references cited.

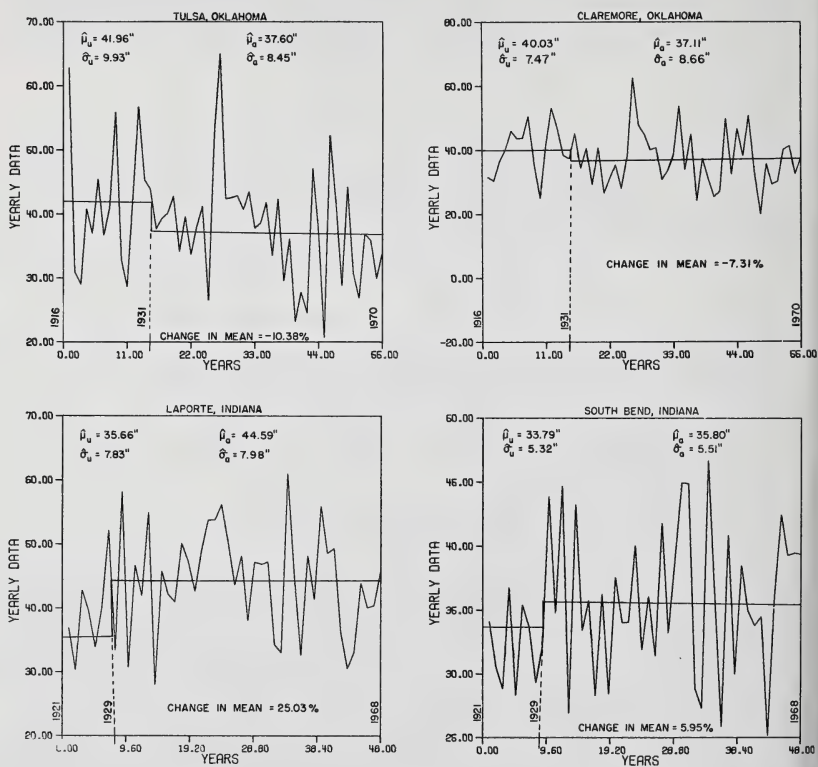


FIGURE 2. Variation in annual rainfall at some representative stations.

Statistical Tests Used in the Study

The statistical tests used in the study are of the nature of hypothesis testing. In the following discussion, the null and alternative hypotheses are represented as H_0 and H_a , and the annual precipitation values in the affected and unaffected periods are respectively designated as P_i and P_j . The total number of P_i and P_j values are n and m , and $N = n+m$. The significance level at which the null hypothesis is

rejected is represented by α and α was fixed at 5% for all the tests. The details of all the tests may be found in standard reference works (1).

Rank Test

The null hypothesis H_0 to be accepted or rejected by the application of the rank test is that the affected and unaffected period populations are identical.

The test statistic Z_0 is given by Equation 1, in which T_a is the sum of rank of precipitation values in the affected period.

$$Z_0 = \frac{\bar{T}_a - T}{\sigma} \quad [1]$$

The precipitation values P_i and P_j are combined and ranked in increasing order such that (if there are no ties) the smallest and largest values have ranks 1 and N . The value of T_a is estimated by adding the ranks of precipitation values in the affected period. $\bar{T}$ and σ are given in Equation 2.

$$\left. \begin{aligned} \bar{T} &= \frac{m(n+m+1)}{2} = \text{expected value of } T_a. \\ \sigma^2 &= m(n)(n+m+1)/12 \end{aligned} \right\} \quad [2]$$

The decision rule for the Rank test is given below.

If $Z_0 > N_{1-\alpha}$: reject H_0 (Affected and unaffected period populations are not identical).

If $Z_0 \leq N_{1-\alpha}$: accept H_0 (Affected and unaffected period populations are identical).

$N_{1-\alpha}$ is the value of the unit normal variate at a significance level α .

The results of the rank test given in Table 1 indicate that the null hypothesis can be accepted for the data from all the stations. Consequently, for the data from all, no statistically significant changes may be claimed to be present in the populations from the affected and unaffected periods.

TABLE 1. Summary of results of rank test.

Station	Test Statistic Z_0	Critical Value $N_{1-\alpha}$	Is $Z_0 > N_{1-\alpha}$?
Indiana			
LaPorte	-1.1484	1.645	No
South Bend	1.2180	1.645	No
Valparaiso	-.2204	1.645	No
Plymouth	.2436	1.645	No
Oklahoma			
Tulsa	-1.3796	1.645	No
Claremore	-1.3229	1.645	No
Cleveland	-.6992	1.645	No
Muskogee	0.1701	1.645	No

Mann-Whitney U-test

The null and alternate hypotheses H_0 and H_a tested by the Mann-Whitney U-test are: H_0 : P_i and P_j have the same distribution; H_a : the location parameter of P_j is greater than the location parameter P_i . The test statistic w is defined in Equation 3.

$$w = \frac{U_M - \bar{U}_M}{\sigma_M} \quad [3]$$

In Equation 3, U_M is the number of times P_j values are larger than P_i values. U_M is estimated by using Equation 4, in which T_a is the sum of ranks of precipitation values in the affected period (see Rank Test).

$$U_M = nm + \frac{m(m+1)}{2} - T_a \quad [4]$$

$$\bar{U}_M = \frac{nm}{2} ; \sigma_M = \frac{nm(n+m+1)}{12} \quad [5]$$

The decision rule for the test is that if $w > N_{1-\alpha}$, then the null hypothesis is rejected. From the results shown in Table 2, it can be seen that the null hypothesis must be accepted for the data from all the stations. The implication is that the probability distributions of the data from unaffected and affected periods are not statistically significant. Although the Rank and the Mann-Whitney U-tests are similar, the Mann-Whitney U-test is more powerful.

TABLE 2. Summary of results of Mann-Whitney U-test.

Station	Test Statistic W	Critical Value $N_{1-\alpha}$	Is $W > N_{1-\alpha}$?
Indiana			
LaPorte -----	1.1484	1.645	No
South Bend -----	-1.2180	1.645	No
Valparaiso -----	.2204	1.645	No
Plymouth -----	-.2436	1.645	No
Oklahoma			
Tulsa -----	1.3796	1.645	No
Claremore -----	1.3229	1.645	No
Cleveland -----	.6992	1.645	No
Muskogee -----	-.1701	1.645	No

Run Test

The null hypothesis H_0 in the run test is similar to that of the Rank test and is given below.

H_0 : The samples from the affected and unaffected periods arise from the same distribution.

The statistic U_R used in the run test is defined in Equation 6 in terms of the expected value $\bar{r}$ and standard deviation σ_r of run lengths. A run is defined as an unbroken sequence of values of P_i or P_j .

$$U_R = \frac{r - \bar{r}}{\sigma_r} \quad [6]$$

If the samples P_i and P_j are from the same population, then the observations in the unaffected and affected periods will be well mixed and the number of runs will be large. Mean $\bar{r}$ and the standard deviation σ_r of runs are computed by Equations 7 and 8.

$$\bar{r} = \frac{2nm}{N} \quad [7]$$

$$\sigma_r = \frac{\sqrt{2nm(2nm - m - n)}}{N^2(n + m - 1)} \quad [8]$$

The decision rule is that if $U_R > N_{1-\alpha}$, then the null hypothesis is rejected at a level of significance α . From the results of Run Test presented in Table 3, the null hypothesis can be rejected for data from all the stations except LaPorte and Plymouth.

TABLE 3. Summary of results of run test.

Station	Test Statistic U_R	Critical Value $N_{1-\alpha}$	Is $U_R > N_{1-\alpha}$?
Indiana			
LaPorte	2.64	1.645	Yes
South Bend	1.301	1.645	No
Valparaiso	.357	1.645	No
Plymouth	1.873	1.645	Yes
Oklahoma			
Tulsa	0.283	1.645	No
Claremore	1.097	1.645	No
Cleveland	1.096	1.645	No
Muskogee	0.407	1.645	No

Median Test

The median test is used to test the significance of the change in the median values of the data from the affected and unaffected periods. The null hypothesis for this test is given below.

H_0 : There is no change in the median values of the data from the affected and unaffected periods.

The data from the affected and unaffected periods are combined and arranged in the increasing order of magnitude. The number of P_i and

P_j values above and below the combined median values are determined. Let the number of P_i values above and below the combined median be n_{1a} and n_{1b} and the number of P_j values above and below the combined median be n_{2a} and n_{2b} . The test statistic M is defined as in Equation 9.

$$M = \frac{(|2n_{1a} - (n_{1a} + n_{1b})| - 1)^2}{n} + \frac{(|2n_{2a} - (n_{2a} + n_{2b})| - 1)^2}{m} \quad [9]$$

If $M > \chi_{1-\alpha}^2(1)$ then the null hypothesis that there is a change in the median values of data from the affected and unaffected periods is rejected. The results obtained by applying the median test to the data from several stations in Indiana and Oklahoma shown in Table 4 indicate that there is no statistically significant change in the median values from affected and unaffected periods.

TABLE 4. Summary of results of median test.

Station	Test Statistic M	Critical Value $\chi_{1-\alpha}^2(1)$	Is $M > \chi_{1-\alpha}^2(1)?$
Indiana			
LaPorte -----	1.6879	3.841	No
South Bend -----	1.6489	3.841	No
Valparaiso -----	0.0074	3.841	No
Plymouth -----	0.4220	3.841	No
Oklahoma			
Tulsa -----	.2917	3.841	No
Claremore -----	0.2917	3.841	No
Cleveland -----	0.2917	3.841	No
Muskogee -----	0.0250	3.841	No

U-test

The statistical significance of the change in the mean value of precipitation in the unaffected and affected periods is tested by the U-test in which the following assumptions are made: 1) The precipitation data are normally distributed; 2) the precipitation values are uncorrelated; 3) the population parameters of precipitation are known. The first two assumptions are approximately valid for the data considered in the present study, whereas the third assumption cannot be verified.

The test statistic U_0 is defined in terms of the estimated precipitation mean values in the unaffected (μ_U) and affected (μ_a) periods, and the standard deviations in the unaffected (σ_U) and affected (σ_a) periods. The test statistic U_0 is defined in Equation 10.

H_0 : There is a change in the mean value

$$U_0 = \frac{\mu_a - \mu_U}{\sigma_U / \sqrt{m}} \quad [10]$$

If the value of the statistic U_0 is larger than N_{1-a} then the null hypothesis H_0 is accepted. The results of application of the U-test to the data from Indiana and Oklahoma (Table 5) indicate that the null hypothesis can be accepted only for the data from LaPorte. In other words, the change in the mean values in the data from LaPorte are statistically significant.

TABLE 5. Summary of results of U-test.

Station	Test Statistic U_0	Critical Value N_{1-a}	Is $U_0 > N_{1-a}$
Indiana			
LaPorte -----	7.2142	1.645	Yes
South Bend -----	0.391	1.645	No
Valparaiso -----	0.1564	1.645	No
Plymouth -----	0.4863	1.645	No
Oklahoma			
Tulsa -----	-1.4248	1.645	No
Claremore -----	-1.518	1.645	No
Cleveland -----	-.8658	1.645	No
Muskogee -----	-.2061	1.645	No

Discussion and Conclusions

Of the five statistical tests discussed previously, the rank test, the Mann-Whitney U-test, and the run test deal with testing the significance of the changes in annual rainfall probability distributions in the affected and unaffected periods. The median test and the U-test are used to test the significance of changes in the median and mean values of annual rainfall in the unaffected and affected periods.

The results from the rank, and the run tests indicate that there may be significant changes in the probability distribution of annual precipitation at LaPorte, whereas the result from Mann-Whitney U-test gives the opposite result. Since the Mann-Whitney U-test is more powerful than the other two tests, the probability distributions of the precipitation data from the affected and unaffected periods may be assumed to be the same. This aspect, however, needs further study. The median values do not appear to have changed significantly from the unaffected to the affected period. The mean values of the data from LaPorte, on the other hand, appear to have increased from the unaffected to the affected period. Further analyses, which are not included here, also indicated a significant increase in the mean value in the data from LaPorte.

In view of these considerations the following conclusions may be drawn.

- 1) There is a statistically significant increase in mean annual rainfall at Laporte, Indiana, and Bristow, Oklahoma, which may be attributed to the effects of urbanization and industrialization.

- 2) The probability distributions and the median values of annual precipitation data do not appear to have been affected significantly.

Acknowledgments

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ENTOMOLOGY

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36 West Roberts Road, Indianapolis, Indiana 46217

DARRYL P. SANDERS, Department of Entomology,
Purdue University, West Lafayette, Indiana 47907
was elected Chairman for 1974

ABSTRACTS

A Preliminary Report of Mosquito Population Sampling Methods in Delaware County, Indiana, 1973. GREGORY L. SPANGLER and R. E. SIVERLY, Public Health Entomology Laboratory, Ball State University, Muncie, Indiana 47306.—Three sites were selected in Delaware County to evaluate and compare egg sampling, larval sampling, and adult sampling as indicators of species, number of species, and seasonal occurrence of indigenous mosquito populations.

At each field study site stakes were set 2 to 22 feet apart on successive dates at different waterline levels. A minimum of three contours were thus established at each site. Egg samples were obtained by removing topsoil sections 6 x 6 x 1 inches at various levels on the profiles of the study sites. Eggs were isolated using the mechanical separation and flotation method developed by Horsfall and co-workers.

These studies are ongoing and complete data will not be obtained this year. Eggs from all loci will be identified and relegated to time of oviposition as well as place of oviposition. Special relations to eggs deposited by other species will be determined, and identifiable ecological factors, such as proximity to logs, saturation, etc.

Larval sampling was done by dipping with a standard pint-sized enameled dipper. Most data were qualitative, but in some cases estimations of total populations were made. This method tended to exaggerate the prevalence of one or a few species and not to reveal the presence of others.

Adult collections were obtained by using battery-operated light traps (with carbon dioxide) and taking biting collections. These data tended to reveal more than the species indigenous to the specific study site due to infiltration.

Non-Random Segregation of Interchange Complexes in a Compound Structural Rearrangement (Translocation + Inversion) in the Mosquito, *Aedes aegypti*. JAMES J. MCGIVERN, Department of Biology, University of Notre Dame, Notre Dame, Indiana 46556.—A compound structural rearrangement, designated $T(1;2)1Mc + In(2)b$ was induced by gamma irradiation. This rearrangement was originally detected through suppression of recombination between certain markers in linkage groups I and II and observation of pseudolinkage between markers on those same linkage groups. An analysis of the orientation of metaphase chromosomes was done and a high frequency of alternate segregation

(86%) was observed. This phenomenon may be related to the cytological features of this rearrangement, and it is the first report in any mosquito species of directed orientation of multiple associations of chromosomes.

Notes on Identification and Biology of *BufoLucilia silvarum* (Meigen) (Diptera, Calliphoridae) in East-Central Indiana. R. E. SIVERLY and JOHN JOYNER, Public Health Entomology Laboratory, Ball State University, Muncie, Indiana 47306.—The ratio of head length to head height as cited by Hall is not considered a reliable character for separation of *BufoLucilia silvarum* from similar and more prevalent species, particularly *Phaenicia sericata*. The erect, medial, marginal bristles on the second abdominal segment and the dark basicosta appear to be more reliable characters for identification of *B. silvarum* than head length: height ratio.

BufoLucilia silvarum was present in traps baited with chicken entrails from May through August 1973. This species comprised approximately four per cent of trap collections. Further studies are planned which should elucidate certain aspects of its biology, particularly the extent of its parasitism upon amphibia.

Review of Findings on the Taxonomic Status of *Culex pipiens* L. and *Culex fatigans* Wiedemann in the United States. J. W. BURGESS, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.—The taxonomic relationship of two members of the *Culex*-complex, *C. pipiens* and *C. fatigans*, has been the object of much previous study. Literature yields examples of fertile crosses between the two groups resulting in offspring which resemble natural "intermediates". Mating preference, swarming behavior and feeding behavior seem, in some cases, to provide no natural isolating mechanism. In other cases, crosses have been shown to be infertile, or seldom fertile. Climatic tolerance, ability to utilize fat reserves for hibernation, and population response to feeding and swarming have all been cited as examples of natural barriers.

Due to the morphological similarity of the two groups, it is difficult to ascertain whether past literature was based on accurate determinations. Characters to date are unsatisfactorily variable, and several vary with environmental conditions. Future researchers in this area are urged to record any environmental data which might affect their determinations.

Both *Culex pipiens* and *C. fatigans* exhibit distinctive behavioral patterns regarding host preference, mating patterns, temperature and photoperiodic response, and capability of gonadotropic dissociation, which may be used to distinguish them. However, presently it is not possible to decide the taxonomic relationship of these two groups. Both show discrete characteristics, but conclusive population relations in the field have not yet been demonstrated.

Biology of *Bellura gortynoides* Walker (= *vulnifica* [Grote]), the Yellow Water Lily Borer (Lepidoptera: Noctuidae). ELI LEVINE, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.—

Keys to the species of *Bellura* whose larvae feed on yellow water lily, *Nuphar advena*, are based largely on the color of the anal tuft of the female moth. Research conducted during the spring and summer of 1973 has shown that dark brown-tailed females (*B. vulnifica* Grote, 1872) give rise to white-tailed daughters (*B. gortynoides* Walker, 1865).

There are two complete generations per year in the Tippecanoe County area. Eggs are laid in masses on both upper and lower surfaces of emergent leaves of yellow water lily. First generation eggs are laid in late May-early June and are well covered with brownish hair from the female's anal tuft. Fertile eggs hatch within 6 days. For approximately the first three instars, the larvae are leaf miners; thereafter, they become petiole borers. There is a total of six or seven instars, and last instar larvae average about 5.5 centimeters in length. The larvae pupate in the water-filled bores of the petioles. Throughout most of July, white-tailed females emerge, mate and lay white-covered second generation egg masses. As in the first generation, second generation larvae pass through leaf mining and petiole boring stages. Between mid-September and November, the larvae swim to shore and overwinter as larvae under the bark of trees, in rotten wood, or under leaf litter.

Both first and second generation eggs are highly parasitized by *Telenomus arзамae* Riley (Hymenoptera: Scelionidae). First, and to an even greater extent, second generation larval populations are limited by an ichneumonid parasite and a polyhedrosis virus.

A Preliminary Study of Autogeny in Stenogamous and Non-stenogamous Strains of *Culex pipiens pipiens* (Northern House Mosquito). THOMAS M. LEE and R. E. SIVERLY, Public Health Entomology Laboratory, Ball State University, Muncie, Indiana 47306.—Two strains of *Culex pipiens pipiens* were reared in the laboratory to compare the frequency of the expression of autogeny in each strain. A stenogamous strain was established from egg rafts taken from storm sewer catch basins located in Muncie. A previously established non-stenogamous strain originated from egg rafts collected from an open, unshaded industrial waste lagoon.

Larvae were obtained from egg rafts produced by the laboratory colonies and were reared under standardized conditions. Adults emerged in 1 x 1 x 1-foot screened cages and then were transferred to pint-sized cardboard cartons and maintained on a 10 per cent honey solution.

A total of 748 females, all of which were at least 5 days old, were dissected, their ovaries removed, and categorized according to Christophers' classification.

Both strains exhibited a low frequency of autogeny. Further study is indicated to establish physiological and/or environmental factors which influence autogeny in this species.

Evaluation of ALTOSID SL-10 in Controlling Mosquito Populations in an Industrial Waste Lagoon Complex. THOMAS M. LEE and R. E. SIVERLY, Public Health Entomology Laboratory, Ball State University,

Muncie, Indiana 47306.—A previous study (Shroyer and Siverly, 1970) reported a population potential of immature mosquitoes in excess of 300 million at one waste lagoon complex in central Indiana. Observations attending use of FLIT-MLO in 1972 suggested that control might be achieved by treatment of the first lagoon in the series, since overflow from the first to the second lagoon frequently occurred.

ALTOSID SL-10 was the treatment compound used in 1973. This is a synthetic, hormonomimetic compound which imitates natural juvenile hormone and causes abnormal larval development in late fourth instar. Lagoon I was sprayed weekly with a water-flowable mixture at the rate of 12 ounces per acre. The second lagoon was untreated.

Evaluation was based on estimated numbers of immatures derived by sampling with a standard pint-sized dipper. Each weekly count was an average of at least 25 dips.

ALTOSID SL-10 did not effect control in either lagoon and in fact was inferior in performance to FLIT-MLO in 1972. Population control of immatures at this lagoon complex is extremely difficult, however, due to fluctuations in water level, turbulence, overflow, and a high organic content of the waste material. Further trials are planned with compounds which meet Environmental Protection Agency standards, and which can be applied either with a hand sprayer or broadcast by hand.

Observations on the Biology of *Mansonia perturbans* (Walker) (Diptera, Culicidae) in Indiana. R. E. SIVERLY, Public Health Entomology Laboratory, Ball State University, Muncie, Indiana 47306.—Wild-captured females fed readily in small cages, either on warmed beef blood or on the human hand. Egg rafts were laid in small plastic cups provided with floating cork discs. Rafts consisted of 100-150 eggs. Eggs measured approximately 500 microns in length and 100 microns at the anterior diameter. At room temperature, eggs hatched in 5 or 6 days after oviposition.

Larvae were free-swimming during early life but attached to submerged roots of cattail in second instar. Larvae tended to aggregate on one root system or even one root, but they changed positions frequently and re-attached without apparent difficulty. Larvae surfaced if root tracheal systems failed to transport air.

Pupation occurred at the sites of larval attachment. Unlike larvae, pupae were unable to transfer from one attachment site to another. Darkening of the pupal integument was concurrent with loosening of the respiratory trumpets at the points of attachment. Adult emergence occurred within a few hours after surfacing of mature pupae.

NOTE

A New Barberry Pest Found in Indiana.¹ DONALD L. SCHUDER, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.—The barberry looper, *Coryphista meadii* (Packard), (Lepi-

¹ Journal Paper No. 5306, Purdue University Agricultural Experiment Station.

doptera, Geometridae) is a pest of barberry and mahonia (2). The insect was first described from Colorado in 1874. Two color variations were noted. The looper was reported from Ohio and other eastern states in the early 1940's (4). It was found defoliating an ornamental barberry planting in West Lafayette in the summer of 1973. According to the owner, defoliation also occurred in 1972, but the problem was not reported to the writer until this year.

The insect has been reported feeding on *Berberis thunbergii* (D.C.) (Japanese barberry) and its varieties: *B. thunbergii minor* (Rehd.); *B. thunbergii atropurpurea* (Chenault); *B. thunbergii erecta* Rehd. (3); *B. repens* Lindl. (1); and *Mahonia aquifolium* (Pursh.) Nutt. (Oregon grape) (3).

The moths are buff to smoky brown with a wavy pattern on the wings. They are nocturnal, but when flushed during the daylight hours they fly rapidly in a zigzag pattern. In late June and early July the females deposit their yellow, oval, flattened eggs singly on the lower surface of leaves (1, 2). The incubation period varies with the temperature but is usually 3 to 4 days during midsummer. The larvae require 12 to 16 days to complete development. Full-grown larvae are about 1 inch long. The head is orange and the body is very dark brown to black. A lateral light colored stripe extends the full length of the body and is punctuated with black spiracles. The larvae are nocturnal and can be found best by checking the plants with a flashlight. Pupation occurs in a cell in the soil, or in a cocoon of leaves and litter at the soil surface and lasts 11 days during the summer months (3). The pupa is a shiny dark brown. Thus, a life cycle is completed in about 4 weeks, but there are three or more overlapping generations. The larvae can be found from early July until cold, freezing weather (3, 4). The insect overwinters in the pupal stage.

The caterpillars feed on the margins of the barberry leaves causing them to have a ragged appearance (3). Heavy populations completely defoliate the host plants. On mahonia the larvae tend to feed on the lower leaf surfaces producing a skeletonized appearance.

Neiswander (3) and Sun (4) have reported five hymenopterous pupal parasites, three dipterous parasites, and a pentatomid predator.

Acknowledgment

I would like to thank Professor George L. Godfrey of the University of Illinois for identification of the original specimens.

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New Distribution Records of Mosquitoes in Indiana, 1973 (Diptera: Culicidae)

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Abstract

Fifty-six new Indiana county records were obtained during the spring and summer of 1973, based primarily on mosquito biting collections. Nineteen of these were new records of genera. Most of the records involved common species, principally *Aedes sticticus* (Meigen), *Aedes stimulans* (Walker), *Aedes fitchii* (Felt and Young), *Aedes trivittatus* (Coquillett), *Aedes triseriatus* (Say), and *Aedes vexans* (Meigen).

The most comprehensive source of information on the distribution of mosquito species in Indiana is Siverly's recent publication, *Mosquitoes of Indiana* (1). However, since few workers are studying the native mosquito fauna, many portions of the state have been poorly examined. Therefore, species composition of some counties is totally unknown. Accurate knowledge of species composition of any local area is essential for intelligent, effective control, as well as for understanding the potential for disease transmission.

Methods and Results

Though collection of adults was emphasized, populations of immature mosquitoes were also sampled during the spring and summer of 1973. Adult populations were sampled by collection of biting females, whereas aquatic stages were collected with a long-handled pint dipper.

Larvae and adults were identified to species, while pupae were allowed to complete development prior to identification in the adult stage. Since identification keys to the *Culex* egg rafts were not available, egg rafts were allowed to hatch and the larvae produced were identified.

As a result of these mosquito collections, 56 new records involving 25 counties were obtained in Indiana (Table 1). Most of these records were derived from collections of biting females. No new state records were obtained.

It is hoped that further efforts will be made to obtain a more complete picture of mosquito distribution in the state, and to detect temporal changes in the occurrence of species.

TABLE 1. *New records of mosquito distribution in Indiana, 1973.*

Counties	Species ¹																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Adams -----		x	x	x			x											
Cass -----		x		x		x	x											
Daviess -----			x															
Dubois -----			x				x	x										
Elkhart -----		x	x															
Fulton -----		x	x	x														
Gibson -----								x	x	x	x	x						
Greene -----															x			
Harrison -----													x					
Jackson -----			x			x												
Jasper -----			x															
Jennings -----	x																	
LaPorte -----					x	x												
Noble -----		x	x															
Orange -----														x ²				
Parke -----			x															
Pike -----			x		x												x	
Shelby -----						x												
Starke -----			x	x		x	x											x
Sullivan -----	x					x												
Vermillion -----							x											
Warren -----			x		x													
Warrick -----											x							
Wells -----		x		x	x	x										x		
Whitley -----		x		x														

¹ Species code: 1-*Aedes canadensis canadensis* (Theobald); 2-*Aedes fitchii* (Felt and Young); 3-*Aedes sticticus* (Meigen); 4-*Aedes stimulans* (Walker); 5-*Aedes triseriatus* (Say); 6-*Aedes trivittatus* (Coquillett); 7-*Aedes vexans* (Meigen); 8-*Anopheles punctipennis* (Say); 9-*Anopheles quadrimaculatus* Say; 10-*Culex pipiens pipiens* Linnaeus; 11-*Culex restuans* Theobald; 12-*Culex territans* Walker; 13-*Culiseta inornata* (Williston); 14-*Psorophora cyanescens* (Coquillett); 15-*Psorophora ferox* (Humboldt); 16-*Psorophora horrida* (Dyar and Knab); 17-*Psorophora varipes* (Coquillett); 18-*Coquillettidia perturbans* (Walker).

² This collection was made in 1972.

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Prey-taking among some Indiana Solitary Wasps (Hymenoptera: Sphecidae)

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Abstract

Several instances of prey-taking from *Sceliphron caementarium* (Drury) and *Chalybion californicum* (Saussure) nests by females of the same species are reported from Wayne County, Indiana. Taking of stored prey from *S. caementarium* by an ant, *Crematogaster l. lineolata* (Say), is also noted. Prey items in all instances were spiders. These were removed whole from the mud cells by the wasps but were cut into fragments by the ants.

Introduction

Prey-taking is the acquisition of food which one insect has already selected as food for itself or its larva, by another insect. This behavior can occur either when the adult insect is carrying food back to a nest cell or after the food has been stored. Some insects which usually gather food for their larvae from the natural habitat of the prey occasionally resort to taking prey previously gathered by a member of the same species. This may be food which is characteristic for the group, such as certain spiders used by mud-dauber wasps of the Sphecidae. In addition, food may be taken by ants or scavenger wasps. Therefore prey-taking can be either intraspecific or interspecific. Examples of both have been observed in Wayne County, Indiana.

Review of Literature

Morley (5), North Carolina, reported that she saw *Sceliphron caementarium* (Drury) taking spiders from another nest being provisioned by a female of the same species. In 1930, Bruch (1), Argentina, reported *Sceliphron figulus* (Dahlbom) taking spiders from females of that species. Rau (6), Missouri, described the opening of a nest of *S. caementarium* by a female *Chalybion californicum* (Saussure) and the removing of seven spiders. Instead of taking the spiders to her nest, she dropped them to the ground. Evans (2) ranked five species of *Bembix* in order of their habit of stealing prey: *B. cinerea* Handlirsch, very common; *B. nubilipennis* Cresson and *B. texana* Cresson, common; *B. spinolae* Lepeletier, common in dense colonies, and *B. pruinosa* Fox, rare. He also found that *Microbembix monodonta* (Say) frequently took dead arthropods from workers of the ant, *Formica fusca* L., and that *Bembix texana* females tried to take flies from a larger wasp, *Stictia carolina* (Fabricius) (3).

Wheeler (7) said that many small ants fed on the extra food in a nest of larger ants or took food from workers as they carried it back to their nest. He used the term "cleptobiosis" for this behavior. Evans (2) stated that there may be "some correlation between proximity of nests and frequency of robbing." Evans and Eberhard (4) referred

to insects which used the stored food of other insects for their offspring as cleptoparasites.

Results of Observations

Five observations of ants taking spider prey collected by the yellow-legged mud-dauber wasp, *Sceliphron caementarium*, have been recorded for Wayne County. These were seen in the upper level of a tool shed on a farm near Centerville. The ants, *Crematogaster l. lineolata* (Say), were identified by Leland Chandler, Entomology Department, Purdue University. During the first observation, the female wasp had completed one mud cell, stocked it with spiders, and sealed the end. A second cell was being filled when I noticed a procession of ants at the cell and on the rafter to which it was attached. One small crab spider was being carried out of the nest and another spider had been cut to pieces by the ants. They were carrying off bits of legs and other fragments. This occurred about 4:30 PM. At 8 PM the wasp placed a thin mud plug across the end of the empty cell.

The following morning the wasp had opened the cell by 8:45 AM and had begun to bring more spiders. At 11:25 AM a procession of ants arrived and they resumed cutting and carrying off parts of spiders. This disturbance caused the wasp to abandon her nest. She built a new nest several feet away and successfully filled five cells. Ants were never seen opening cells that had been sealed.

Two wasps showed aggressive behavior toward the ants, but apparently made no attempt to sting. Instead, the wasps picked up ants in their mandibles and threw them to the floor of the tool shed. Upon examination, these ants showed signs of being crushed by the wasps' mandibles. In 5 min, five ants were thrown down by one *S. caementarium*, but this was ineffective in halting the procession. These attacks were not successful, because there were many ants that took the places of the injured ones. In two other instances, the wasps made no attempt to defend their nests. In all instances, the wasps abandoned their nests, usually building elsewhere in the shed.

One example of spiders taken from the blue wasp, *Chalybion californicum*, by another female, *C. californicum*, was recorded July 21, 1967. The wasp was filling a cell in a deserted nest of *Sceliphron caementarium*. She had been bringing in spiders from 9:20 AM to 12:25 PM, when a smaller *C. californicum* arrived at the cell while she was away. The second wasp took a spider and flew away, then returned to the cell and took another spider. When she came back the third time, the nesting wasp was present on the cell. They fought and fell to the floor of the shed while clasping each other. The smaller wasp flew out the doorway. The nesting wasp returned to her nest and began closing the cell with mud scraped off the same nest about 2 inches away from the cell.

No examples of *Chalybion californicum* taking prey from nests of *Sceliphron caementarium*, such as Rau (6) reported, have been observed.

Five instances of spiders taken from *Sceliphron caementarium* by wasps of the same species have been observed. When approaching the nest these wasps often land 10 to 14 inches from it, then walk the rest of the way. The first instance was an attack on *S. caementarium* as she walked along a rafter carrying a large spider to her nest. In the second instance, a cell was emptied of spiders by a female wasp between 11:55 AM and 1:33 PM. At least three spiders had been in the cell, but the total was not determined. In the third and fourth instances, on two different occasions, two wasps defended their nests successfully against females of the same species by flying rapidly at the intruders, sometimes falling to the ground grasping each other. In the fifth situation, there was taking and re-taking. Three wasps, all *S. caementarium*, were involved. One, Wasp 33, took two spiders from Cell 55 before its maker, Wasp 55, closed her cell. There was conflict twice between Wasps 33 and 55. Then, Wasp 47 took one of the spiders from the cell of Wasp 33. This spider had been taken earlier from Wasp 55. Then Cell 47 was sealed. Wasp 33 inspected Cells 52 and 32 before returning to Cell 55. This hunt was unsuccessful, because Cell 52 was empty, Cell 32 was being closed and Cell 55 was already closed. It appears that cells that have been attacked may be sealed before they are filled, but more observations are needed to prove or disprove this. The closure may be similar to the thin seal that is made over an incompletely filled cell in the late afternoon, and removed the following day when filling resumes.

Conclusion

Taking of prey from one wasp by another of the same species is not uncommon among the mud-dauber wasps, but the frequency of this behavior may depend upon proximity of nests. Ants commonly take food from mud cells and may cause wasps to desert some locations and build elsewhere. Ants entered nests before sealing but were not seen opening cells that had been sealed. No instance of spider-taking by *Chalybion californicum* from cells of *Sceliphron caementarium* was found.

Acknowledgments

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Preliminary Studies of Collembola at the Brookville Ecological Research Center, Including New Records of Indiana Springtails

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Abstract

More than 16,000 Collembola were collected and examined during a 3-year study at the Brookville Ecological Research Center in east-central Indiana. Research data are presented, including records of 10 species new to the state.

Studies of plant and animal ecology at the Brookville Ecological Research Center (BERC) in east-central Indiana were begun in 1970. A farm of 110 acres at the upper end of the Brookville Lake site was leased to Earlham College and Miami University by the Army Corps of Engineers and was utilized in this research.

Collembolan study at the center was instituted to inventory the species present, to record changes in springtail populations as the abandoned farm undergoes succession, and to add to the understanding of the dynamics of collembolan populations.

Methods

Regular monthly sampling of Collembola started in August 1970, and during the following 36 months, 33 collection visits were made to the Brookville Ecological Research Center (BERC). A total of 162 cores was taken. Two abandoned crop fields were selected for regular monthly sampling, and areas for occasional sampling were selected in the woodlot, pasture, and floodplain crop field. The last year of cropping at BERC was 1969 when Field 1 was planted in corn and Field 2 in soybeans. Field 3, a rotation crop field still being farmed by the neighbor adjacent to the center on the east, was added for regular sampling in May of 1971. All of the areas from which samples were taken have been soil mapped by the U.S. Soil Conservation Service. The three regularly sampled crop fields were mapped as Ockley, 0-2% slope, with slight erosion. Field 1 is silt loam texture, and Field 2 is loam. During the 3-year study, more than 16,000 Collembola were collected and examined; 12,396 of these were from Fields 1, 2, and 3. Cores 10 cm in diameter and, depending on soil conditions, varying between 5 cm and 10 cm in thickness were collected and transported to the laboratory. A heat separating funnel was used to extract the Collembola.

This study considers the springtails in 10 family or subfamily groups. The Isotomidae because of the extreme variations within the family have been divided into three subfamilies, and the Sminthuridae into two subfamilies. For statistical consideration, specimens determined to species during the research have been recombined into the 10 larger groupings.

Species Present

Fifty-seven species occurring at BERC are listed. Asterisks denote six records new to Indiana, and unless otherwise noted, specimens were collected from cropland sites.

- Mesaphorura clavata* (Mills)
Hymenaphorura subtenuis (Folsom),
 floodplain
Protaphorura encarpata (Denis)
Xenylla grisea Axelson
X. humicola (Fabricius)
 * *Hypogastrura denticulata* (Bagnall),
 floodplain
H. matura (Folsom)
Odontella cornifer Mills
Friesca claviseta Axelson
Pseudachorutes lunatus Folsom, floodplain
P. saxatilis Macnamara
P. subcrassoides Mills
P. undescribed species
Paranura caeca Folsom, woodlot
Neanura pseudoquadriculata Stach
Micanurida undescribed species
Tomocerus species
Folsomides parvus Folsom
F. stachi Folsom
 * *Isotomodes tenuis* Folsom
Holotoma elongata (MacGillivray)
Folsomia fimetaria (Linné)
Proisotoma near *hankoi* Stach
P. minuta (Tullberg)
 * *P. vernoga* (Wray)
Isotomurus palustris (Müller)
 * *I. palustris balteatus* (Reuter),
 woodlot
Spinisotoma dispersa Wray
Pseudisotoma sensibilis (Tullberg)
Isotoma tigrina olivacea (Tullberg)
I. eunotabilis Folsom
I. viridis Bourlet
Vertagopus cinerea (Nicolet)
Orchesella ainsliei Folsom
O. hexfasciata (Harvey)
Sinella curviseta Brook
Entomobrya multifasciata (Tullberg)
Entomobryoides purpurascens (Packard)
Pseudosinella rolfsi Mills
P. violenta (Folsom)
Lepidocyrtus cinereus (Folsom)
L. near paradoxus Uzel
L. unifasciatus James, woodlot
Neelides minutus (Folsom)
Megalothorax incertoides Mills, floodplain
Sminthurides aquaticus (Bourlet)
S. hyogramme Pedigo
Sphaeridia pumilis (Krausbauer)
Arrhopalites caecus (Tullberg)
Sminthurinus aureus (Lubbock)
 * *S. aureus novus* Mills
S. elegans (Fitch), pasture
S. elegans cancellus Maynard, woodlot
 * *Sphyrrotheca curvisetis* (Guthrie), woodlot
Bourletiella hortensis (Fitch)
Deuterosminthurus repandus (Ågren)
Ptenothrix unicolor (Harvey), pasture

Following the suggestion of Dr. Peter Bellinger that *Neanura barberi* (Handschin) is a Mexican species, the name *N. pseudoquadriculata* Stach is substituted for specimens previously reported (5) as *N. barberi*.

Four additional species were recorded for the first time from Indiana during 1973, *Anurophorus laricis* Nicolet (Fayette County,) *Orchesella folsomi* Maynard (Wayne County,) *Sminthurinus quadrimaculatus* (Ryder) (Wayne County,) and *Sminthurus dorsalis* Banks (Wayne County.)

This paper lists 10 new records, bringing the total species and forms of Collembola known to occur in Indiana to 124 (5, 6, 7.)

Study of Populations

The 10 groups into which specimens have been placed and the species predominating in each are as follows:

- Onychiuridae: *Protaphorura encarpata* (Denis) and *Mesaphorura granulata* (Mills)
 Hypogastruridae: *Hypogastrura matura* (Folsom)
 Entomobryidae: *Orchesella ainsliei* Folsom, *Pseudosinella violenta* (Folsom,) *Entomobrya* spp., and *Lepidocyrtus* spp.
 Isotomidae
 Anurophorinae: *Folsomides parvus* Folsom
 Proisotominae: *Proisotoma minuta* (Tullberg,) *P. near hankoi* Stach, *Folsomia fimetaria* (Linné)
 Isotominae: *Isotoma eunotabilis* Folsom

Tomoceridae: species not determined

Neanuridae: *Pseudachorutes* spp. and *Micanurida* sp. nov.

Sminthuridae

Sminthurinae: *Sminthurides aquaticus* (Bourlet) and *Sphaeridia pumilis* (Krausbauer)

Sminthurinae: *Sminthurinus aureus* (Lubbock)

To arrive at the overall ranking of the prominence of the 10 groups reported in Table 1, collections from the three cropland sites were compared using the formula for prominence values from Beals (1). Beals' formula has been used in collembolan population studies in Indiana by Pedigo (9, 10) and by Pedigo and others in Iowa (4, 8.)

$$\text{Prominence Value} = (\text{density}) (\sqrt{\text{frequency}}) \text{ where;}$$

$$\text{Density} = \frac{\text{number of individuals of a species collected; and}}{\text{number of cores collected}}$$

$$\text{Frequency} = \frac{\text{number of cores in which species occurred}}{\text{number of cores collected}}$$

TABLE 1. Prominence values and 3-year totals for 10 groups of Collembola collected in Fields 1, 2, and 3 during the period August 1970 through July 1973.

Family or Subfamily Group	Prominence Value	Total Number Taken 1970-1973
Entomobryidae -----	42.756	4,022
Onychiuridae -----	28.032	2,699
Proisotominae -----	17.455 ¹	2,136 ¹
Hypogastruridae -----	12.275	1,474
Anurophorinae -----	9.836	1,266
Sminthuridinae -----	6.592	799
Sminthurinae -----	5.368	633
Isotominae -----	3.814	539
Tomoceridae -----	1.810	274
Neanuridae -----	1.672	225

¹ An aggregation of 799 specimens of *Proisotoma* from Field 1, April 1970, elevates Proisotominae substantially above Hypogastruridae. The two groups probably occur in nearly equal numbers.

The 3-year's data reflected an uneven distribution of Collembola both by species and by numbers of each species found in the cropland samples studied. The micro-habitats collected were small (235 cm³ to 785 cm³;) yet two sizeable species aggregates were taken, 799 *Proisotoma* near *hankoi* Stach and 441 *Folsomides parvus* Folsom. Other species collected in aggregates of 175 or more were *Isotoma eunotabilis* Folsom and *Hypogastrura matura* (Folsom.)

Christiansen, in a comprehensive review of the bionomics of Collembola (3), notes that some scientists feel that the disturbances of the soil normally encountered in agriculture are of little importance to collembolan populations. Other feel that the reverse is true. BERC studies support both positions, measuring substantial but very short lived depression of numbers of springtails in the surface soil after plowing and planting of a row crop.

The first BERC samples were collected from Fields 1 and 2 in August 1970 about 16 months after plowing and fitting for the row crops in the spring of 1969. From the data in Table 2, one may infer that if there was an initial disturbance of the collembolan populations, recovery required less than 16 months.

Recognizing that the 1970 data from Fields 1 and 2 did not reflect a disturbance, regular collection was initiated from Field 3, a rotation crop field on the adjoining farm. The first sample from this field was taken May 11, 1971, with a newly emerged corn crop present. The effect of the cropping activities on *Collembola* in the top 10 cm was drastic. Only two specimens were extracted. This compares with samples the same day from Fields 1 and 2 of 169 and 549. The number of *Collembola* in samples from Field 3 continued to be appreciably lower than the other two fields through June, July, and August (Table 2). The September sample of 258 from Field 3 compared favorably with 379 from 1 and 264 from 2, indicating a high degree of recovery. Samples from all three locations in September showed large numbers of Onychiuridae and Entomobryidae. Samples from Fields 1 and 2 also contained large numbers of *Folsomides parvus* Folsom (63 and 67, respectively.) This species was not present in the sample from Field 3.

TABLE 2. Monthly collection of *Collembola* from Fields 1, 2, and 3.

Month	1970-1971 Field			1971-1972 Field			1972-1973 Field		
	1	2	3	1	2	3	1	2	3
August -----	185	295	—	190	237	24	34	76	13
September -----	211	216	—	379	264	258	123	22	0
October -----	—	—	—	251	171	52	131	241	148
November -----	218	202	—	108	262	53	66	63	66
December -----	142	326	—	97	99	58	112	39	73
January -----	—	—	—	109	197	42	286	66	51
February -----	120	43	—	255	130	10	85	98	27
March -----	176	350	—	—	—	—	237	131	158
April -----	980	523	—	305	352	202	465	137	134
May -----	169	549	2	98	93	38	123	28	48
June -----	303	78	48	81	144	60	100	38	80
July -----	251	54	15	97	91	40	221	65	14
Totals -----	2755	2636	65	1970	2021	837	1983	1004	812

During the 3-year study, *F. parvus* has been an important species well represented in samples from all BERC collection sites except Field 3. The group total for Anurophorinae in Table 1 is made up almost entirely of this species. Table 3 compares the occurrence of *F. parvus* (individuals showing two eyes on each side) with *F. stachi* (individuals showing one eye on each side.)

A second disturbance of Field 3, one which did not seem to adversely affect collembolan numbers, took place in April 1972 when after a light disking of the corn stubble, oats was seeded. A thin stand

of 3-inch high oats was present April 26 when the monthly sample was collected. The collection of 202 individuals compared favorably with 305 from Field 1 and 352 from Field 2. During May and June the oats was pastured off leaving a partial stand of red clover which provided less than 60% crown cover. Pasturing continued, and severe soil compaction resulted. Tilth of the soil, poor even in 1971 when corn was planted, deteriorated during 1972. Although Field 3 was pastured throughout 1973, emergence of various weeds, particularly foxtail (*Setaria sp.*) improved the cover, possibly contributing to an increase in collembolan populations that year. In spite of densely compacted surface soil, in September 1973 Field 3 yielded a sample with 254 specimens compared with 46 from 2 and 157 from 1. Table 2 presents the 3-year's data from the cropfields.

TABLE 3. Occurrence of *Folsomides parvus* Folsom and *Folsomides stachi* Folsom in Fields 1, 2, and 3 during the 3-year study.

Field Number	Total Collections	<i>Folsomides parvus</i>		<i>Folsomides stachi</i>	
		Collections with Species	Number of Individuals	Collections with Species	Number of Individuals
1	33	22	455	3	4
2	33	18	785	1	1
3	26	1	1	4	8

Considerations for Future Research

Sampling techniques and evaluation of data must take into account the occurrence of both large and moderately large aggregate populations. Investigations must consider separately and in various combinations the effects of numerous factors on species association, population dynamics, species behavior, seasonal response, and possibly other collembolan responses. Following are eight important factors to consider:

- 1) Soil type—particularly as it relates to the internal moisture holding capacity, organic content, pH, and soil aggregate makeup.
- 2) Soil structure—reflecting many management considerations, *e.g.*, cropping sequence, manuring, irrigation, reduced tillage practices, regulated grazing, and artificial drainage.
- 3) Chemical additives—fertilizer, pH amendments, pesticides, and pollutants.
- 4) Site disturbance—fitting for agricultural crops, pasturing, compaction by vehicles or animals (including people,) flooding, clearing, and urbanization.
- 5) Established plant cover—species of plant present, the growth habits of the predominating vegetation, and the thrift of the stand.
- 6) Fauna—with particular reference to species predatory to Collembola or symbiotic with them.

7) Flora—with particular reference to the micro-flora [see Bellinger (2) p. 63].

8) Climate—temperature, moisture (both amount and distribution over time), sunlight and wind.

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Insects and Other Arthropods of Economic Importance in Indiana during 1973¹

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Abstract

The abundance and economic impact of selected arthropods responsible for crop losses, annoyance to man and animals, destruction of food and fiber products as well as the abundance and activity of selected entomological parasites and predators of importance in their control in Indiana during 1973 are discussed.

A brief description of climatic conditions which possibly influenced the size of insect populations and the severity of their attacks directly as well as indirectly through their influence on food crops and cultural practices follows.

The 1973 growing season followed, and was delayed, interrupted and generally disrupted by more than a half year of weather which kept soils filled with water. Either heavy rains, which began in September of 1972, or poor drying conditions which alternated with rainy periods, delayed, and in some cases prevented harvesting in 1972, delayed ground preparation for the 1973 planting season and interfered with corn and bean planting as well as the care and harvesting of the first crop of alfalfa. In fact it was not until mid-May that the corn planting season really got underway. Thirty per cent of all of the 1973 corn crop was planted during the week ending May 29. Although this surge in planting brought the corn planting up to the average for that date, additional rain in the following weeks again delayed the planting, so that it was not until the 25th of June that corn planting was 95% complete. The first cutting of alfalfa, at least in the southern third of the state, could not be harvested at the optimum time. The pesticides that should have been applied to first cutting alfalfa had to be omitted or were applied by air.

Corn and Small Grains

Corn earworm (*Heliothis zea* [Boddie]) and fall armyworm (*Spodoptera frugiperda* [J. E. Smith]). Damage due to these species cannot readily be assigned to one or the other unless the larvae are

¹ Journal Paper No. 4260, Purdue University Agriculture Experiment Station. The following includes those who have made identifiable contributions to this summary: Walter L. Stirm (weather and cropping data), F. Tom Turpin (corn soil insects), David L. Matthew (extension data), Robert Gallun and Omelio Sosa (wheat), M. Curtis Wilson (cereal pests, alfalfa weevil parasites), Wayne P. Henderson (*Lasius alienus*), Richard C. Dobson, Christian Christensen (cattle insects), Roger T. Huber (alfalfa, vegetables), John Favinger and James Clark (nurseries, forest and shade trees, economic insects), Donald L. Schuder (ornamentals), Darryl Sanders (horseflies, extension data), C. Richard Edwards (soybeans), Leland Chandler (bees, sheep insects), Donald Schroyer (mosquitoes), H. Randolph Lawson (ants). To these, and to the many others who have made less readily identifiable but nevertheless important contributions, thank you.

present, so they are discussed together. (Of the 77 instances where the larvae were still present at the time of the fall survey, 66 were *H. zea*.) Evidence of the presence of these species in the ears of corn grown for grain (including two popcorn fields) was found in 4.32% of the 4,700 plants examined in the fall survey, up slightly from the 3.39% observed in 1972. The increase was probably due to the lateness of the corn planting. Loss due to these insects was 0.134%, up very slightly from 0.105% in 1972. Their presence in the ears was not always accompanied by loss of kernels; frequently they completed their development at the tip of the ear without ever reaching the kernels, or at most damaging only a few. One *H. zea* was found in the shank of an ear, another inside the cob, while one *S. frugiperda* was found inside the stalk. These are unusual sites for these insects. The southern one-fourth of the state was hardest hit (up to 15% of the ears were attacked in some districts) and the northern one-fourth was second, with little damage between.

Spodoptera frugiperda occurred occasionally in corn whorls in widespread locations when the corn was younger; up to 5% of the field was damaged in one instance. The larvae were also reported as causing damage in wheat in October in the SW district.

European corn borer (*Ostrinia nubilalis* [Hübner]). A heavy second generation appeared this year, somewhat as a surprise, as the first generation was subjected to adverse conditions. Pupation was about 50% complete by mid-May in Tippecanoe Co. (WC), when only about 15% of the corn had even been planted. The flight of first generation adults, as indicated by light trap data, began when only 40% of the corn had been planted, and peak flights were over by mid-June, at which time the average height of the corn that had been planted was but 8 inches. Thus, there was only a small amount of acceptable corn available on which the females could oviposit. Summer surveys showed that about 10% of the emerged corn was infested, with an average in the state of 8.5 borer larvae/100 stalks. Flight of second generation adults, as indicated by light trap data, began throughout the state during the week ending July 16, when corn averaged 44 inches with 5% silked. Flights peaked early in August, when 60% of the corn had not yet reached dough stage. Large acreages of corn with acceptably mature plants, plus good oviposition and hatching weather, combined to the benefit of the borer, and a state average of 110 live larvae/100 stalks was attained by the time of the fall survey in October. District averages ranged from 47 larvae/100 stalks south of Indianapolis (SC) to 194 larvae/100 stalks in the northeastern corner of the state, the highest district average ever encountered in Indiana. Only one other time since 1961 has the state average exceeded 90/100 stalks (in 1971, with an average of a borer per stalk). Of the 4,700 plants examined in the fall survey, 62% were infested.

Western corn rootworm (*Diabrotica virgifera* [Le Conte]). Mid- or late-instar larvae were first observed in a field of corn grown for grain in Porter Co., on June 25, and adults were taken in the same county

on July 10. Damage due to this species was heavier in the NW district and as far east as Elkhart County in the NC district, than in previous years. Its range was extended eastward to counties abutting Ohio, and southward nearly to Indianapolis. Its extension to central Indiana brings the insect to an area where soil conditions at least are more favorable for its development than they were further north. New county records include DeKalb, Allen, Huntington, Clinton, Hamilton and Fountain.

Northern corn rootworm (*Diabrotica longicornis* [Say]). The first adult of the season was seen on July 10, in Pike Co. (SW), and at the same time several adults, still in the soil, were taken in Tippecanoe Co. (WC). There were few if any cases of damage to corn grown for grain in the state in 1973 by this species.

Slugs (Species not determined). In some cases damage was extensive enough to require control measures in young corn grown for grain in several NE and NC fields. In all observed instances the damaged corn followed sod, legumes or diverted acreages.

Corn leaf aphid (*Rhopalosiphum maidis* [Fitch]). This year infestations by this aphid, in corn grown for grain, occurred later relative to corn development than is customary. In the summer survey, taken as nearly as possible while the tassels were still in the whorl, only 9.3% of the stalks observed were infested, mostly only lightly, as compared with 28% in 1972. Eventually, however, 33% of the stalks had aphids, slightly more than in the fall survey of 1972, though the infestations were generally less severe. Because infestations were both late and light, they were probably of little economic consequence.

Oat bird-cherry aphid (*Rhopalosiphum padi* [Linnaeus]). Light infestations were observed in scattered heads of wheat all over the SW and SC districts. At the end of May, scattered heads in small patches were occasionally so heavily infested that they were noticeable from the highway. This was especially true in Knox and Daviess Counties (SW).

English grain aphid (*Macrosiphum avenae* [Fabricius]). Light populations (small colonies on isolated heads of wheat) were observed in many fields in the northern districts by mid-June.

Hessian fly (*Mayetiola destructor* [Say]). Hessian fly populations were lower this year than last. The average number of puparia/100 stems for all varieties was 1.9, compared with 9.1 in 1972. Only 14 fields in seven counties (out of 53 surveyed) had individual fields with infestations of 10% or more, as compared with 27 counties last year. This was probably due in large part to the increased use of varieties which were resistant to the prevailing race of the fly. Resistant varieties averaged 0.4% infested as compared with 6.7% infested in wheat which was susceptible to Race B of the fly. Overall, 1.1% of the stems examined were infested.

Cereal leaf beetle (*Oulema melanopus* [Linnaeus]). Populations were depressed to the point that no economic infestations were either reported or observed during 1973 in oats or wheat.

Cornfield ant (*Lasius alienus* [Foerster]). A swarm of alate males and females a half-mile in diameter was observed on July 20, 1973, at 2:30 PM. in Boone Co. (C) nearly 2 miles south of Lebanon. The swarm was about 3 miles northwest of a heavy thunderstorm. The temperature was 85°F, the wind was SW at about 10 mph. Numbers were great enough to impair the visibility of motorists in the area.

Forage Legumes and Soybeans

Alfalfa weevil (*Hypera postica* [Gyllenhal]). Economic damage from larval feeding occurred in the counties in the southern districts as far north as the counties through which U.S. Highway 50 runs, with sporadic economic infestations north of that area to Shelby and Morgan counties. Economic damage also occurred in the two northern tiers of counties, with a diminution of intensity both eastward and southward from South Bend. Even new fields were not spared in the southern districts, and controls were needed both on the first cutting and often even on the stubble. Rain delayed the harvest and made application of control measures at the appropriate time difficult if not impossible, even by air.

Average counts of larvae in the Daviess Co. (SW) area ranged from 0.5 larvae/stem by March 23 to an average (in six fields) of 4.6 larvae/stem by the 11th of May. Individual fields had averages up to 13 larvae/stem. Similar populations were observed in all of the southern districts, where peak populations occurred later eastward and northward from Daviess County.

The potato leafhopper complex (*Empoasca fabae* [Harris] and possibly other species). This pest was as serious as the alfalfa weevil in alfalfa in 1973. Controls were warranted on all alfalfa on light soils throughout the state, and on all fall-1972 and spring-1973 seeded alfalfa on any soil. This insect probably caused stand reduction in alfalfa. It attacked both the second and third cuttings in the southern districts late in June and in July, and the third in the north, in August.

Mexican bean beetle (*Epilachna varivestis*) [Mulsant]). Populations, generally non-economic, were observed in occasional soybean fields the first week in June in the WC (Clay, Owen, Parke and Putnam Counties) and C (Morgan and Johnson) districts as well as the three southern districts which were usually infested. Few if any developed into problems, and activity was at a low level during July and August. The development of populations which normally occurs in August was delayed until September. At that time, as a result of movement from mature plants to late-planted fields, a few fields accumulated heavy populations. One such field in Lawrence Co., which received the adults from three other fields, had, on September 27, a population which averaged 23/4 feet of row, in addition to a number of other soybean feeders in large numbers. After the soybeans matured the adults moved

to alfalfa fields where they were sometimes quite numerous. A small population of Mexican bean beetles was observed on soybeans in Clinton Co. (C), the farthest north this insect has been observed in numbers on this crop.

Green cloverworm (*Plathypena scabra* [Fabricius]). Economic larval populations were observed in Warrick Co. (SW) and probably occurred, but infrequently, over the state on soybeans. Their large numbers induced some control measures which were probably unwarranted. They peaked in numbers in the southern districts the last week in July, in the rest of the state during August, and disappeared abruptly as a result of disease. Although several species probably were involved, several determinations revealed that they were mostly *P. scabra*. They also attacked alfalfa in some southern districts, occasionally causing economic damage.

Garden symphylan (*Scutigerella* sp.). Symphylans produced a significant reduction in yield in a field of soybeans in Johnson Co. (C), as indicated by a comparison of treated with untreated portions of the field.

Yellowstriped armyworm (*Spodoptera ornithogalli* [Guenée]). Larvae of this species were more frequent in soybean fields than usual. Even so, this colorful larva was not common and posed no threat to the beans.

Vegetable Crops

Potato leafhopper (*Empoasca fabae* [Harris] and possibly other species). These were numerous enough in 1973 to cause widespread hopperburn on potatoes and garden beans, and to reduce the quality of lettuce.

Green peach aphids (*Myzus persicae* [Sulzer]) were hard to control in both southern and northern Indiana peppers. In September, both rose aphids (*Macrosiphum rosae* [Linnaeus]) and potato aphids (*Macrosiphum euphorbiae* [Thomas]) attacked tomatoes and peppers. Tomatoes were also attacked in early August by loopers, in late August by tobacco hornworms (*Manduca sexta* [Linnaeus]). The latter were heavily parasitized. European corn borers (*Ostrinia nubilalis* [Hübner]) were a problem in sweet peppers in August. In June, flea beetles (unidentified species) were a problem on tomatoes in most areas of the state.

Cabbage looper (*Trichoplusia ni* [Hübner]). Larvae occurred in populations of 6-8/cover leaf in cabbage and cauliflower in central and northern Indiana by the end of August. These populations required control measures to insure a marketable product.

Maggots (unidentified species of *Anthomyiidae*) and flea beetles were abundant and reports numerous this year on turnips, radishes and carrots.

Corn flea beetle (*Chaetocnema pulicaria* [Melsheimer]). Adults were a problem on early sweet corn. Later in the year the European corn borer, the corn earworm (*Heliothis zea* [Boddie]) and the fall armyworm

(*Spodoptera frugiperda* [J. E. Smith]) were a problem in sweet corn ears.

Striped cucumber beetle (*Acalymma vittata* [Fabricius]). Adults were numerous (6-8/transplant especially on cantaloupe) by May 18. They were especially difficult to control because of the cold and windy weather which made application of pesticides difficult or ineffective. Attacks were observed in the melon and cucumber growing areas over the state.

Melon aphid (*Aphis gossypii* Glover). This aphid began to accumulate in early August on melons in the southern districts, but remained spotty even in individual fields.

Ornamentals, Forest and Shade Trees

A gall midge (*Taxodiomyia cupressiananassa* [Osten Sacken]). Galls produced by this midge were found on bald cypress (*Taxodium distichum*) trees in Warrick, Spencer (SW) and Perry (SC) Counties December 7, 1972, all new county records.

A geometrid (*Coryphista meadi* [Packard]). Larvae of this species were collected during the summer on barberry and mahonia in Lafayette, Tippecanoe Co. (WC). This is a new county and state record.

Gypsy moth (*Porthetria dispar* [Linnaeus]). An adult was taken in Lake Co. (NW) during the week ending Sept. 21, 1973, in a lure trap. This is a new county and state record.

Jack-pine shoot moth (*Eucosma sonomana* Kearfott). Larvae were collected from shoots of Scotch pine in Elkhart Co. (NC) on June 18, from which adults of this species emerged. This is a new county and a new state record.

Linden looper (*Erannis tiliaria* [Harris]). Larvae of this species almost defoliated a strip of oak woods 150 yards wide by 0.4 mile long in Jasper Co. (NW) during the first week of June. Adults were taken at black light traps on several evenings between Nov. 15 and 25 in Tippecanoe Co. (WC).

Hickory leafroller (*Argyrotaenia juglandana* [Fernald]). About 25% of the terminal leaves of shagbark hickory in an area of Warren Co. (WC), were rolled by the first of June, with about half of the mature larvae dead and mummified.

The larger sod webworm (*Crambus trisectus* [Walker]). The last generation of this species was numerous this year.

Japanese beetle (*Popillia japonica* [Newman]). Adults were trapped in Monroe Co. (SC), for a new county record.

A list of the most-often encountered pests of nurseries, as recorded by the State Entomologist, follows. (The number following the name indicates the number of times that it was encountered during 1973 by nursery inspectors.)

Maple bladdergall mite (<i>Vasates quadripes</i> [Fabricius])	70
Bagworm (<i>Thyridopteryx ephemeraeformis</i> [Haworth])	59
Bronze birch borer (<i>Agrilus anxius</i> Gory)	55

Fletcher scale (<i>Lecanium fletcheri</i> Cockerell)	54
Fall webworm (<i>Hyphantria cunea</i> [Drury])	49
Apple aphid (<i>Aphis pomi</i> De Geer)	43
Cooley spruce gall aphid (<i>Adelges cooleyi</i> [Gillette])	43
Oyster shell scale (<i>Lepidosaphes ulmi</i> [Linnaeus])	40
Spruce spider mite (<i>Oligonychus ununguis</i> [Jacobi])	35
Mimosa webworm (<i>Homadaula anisocentra</i> Meyrick)	34
Honeylocust spider mite (<i>Eotetranychus multidigituli</i> [Ewing])	31
Tuliptree aphid (<i>Macrosiphum liriodendri</i> [Monell])	29
Euonymus scale (<i>Unaspis euonymi</i> [Comstock])	26
Woolly apple aphid (<i>Eriosoma lanigerum</i> [Hausmann])	23
Velvet leaf mite (<i>Eriophyes</i> sp.)	14
Spruce needleminer (<i>Taniva albolineana</i> [Kearfott])	13
Periodical cicada (<i>Magicicada</i> sp.) (XIII brood)	13
Leaf-curl ash aphid (<i>Prociphilus fraxinifolii</i> [Riley])	12
Peachtree borer (<i>Sanninoidea exitiosa</i> [Say])	12
Pine needle scale (<i>Phenacaspis pinifoliae</i> [Fitch])	11
Zimmerman pine moth (<i>Dioryctria zimmermani</i> [Grote])	11
European pine shoot moth (<i>Rhyacionia buoliana</i> [Schiffmüller])	11
Buffalo trechopper (<i>Stictocephala bubalus</i> [Fabricius])	11

Man and Animals

Of the insects that invade Indiana homes either accidentally or for shelter or food, the following were reported more frequently than usual:

Cabinet beetles (*Trogoderma*, several species), and Indian meal moth (*Plodia interpunctella* [Hübner]), both pests in dried cereal grain products, and carpenter ants (*Camponotus* sp.), destructive in wood.

Mosquitoes (several species) were very numerous with a great diversity of species occurring. However, there were not an unusual number of complaints about them. Woodland and other mosquito sources that had been unproductive in several of the last years, this year yielded mosquitoes, sometimes in great numbers.

Head louse (*Pediculus humanus capitis* [De Geer]). Based upon reports and inquiries, this insect is apparently becoming more common.

A deer fly (*Chrysops geminatus impunctus* [Kröber]). A single female of this subspecies was collected on July 4, 1973, in Warren Co. (WC), a new county record. It had previously been collected only in Miami and Union Counties.

Face fly (*Musca autumnalis* [De Geer]). Judging from the reports of both the insect and the incidence of pink eye in cattle, this insect was much more abundant than last year.

Sheep biting louse (*Bovicola ovis* [Schränk]). Unusually heavy infestations were observed on many sheep penned at the Indiana State Fair, and infestations were reported on sheep from several counties.

Sheep bot fly (*Oestrus ovis* [Linnaeus]). These reports refer to a flock of sheep in Warren Co. (WC): first bot expelled April 25; first adult June 17. Adults were virtually absent during the summer months with the lowest numbers in eight years. Significant numbers appeared, however, on August 24-26.

Insidious plant bug (*Orius insidiosus* [Say]). The adults of this species became a nuisance during October because of their numbers in homes and gathering places, and because of their bites.

Beneficial Insects

Bathyplectes anurus [Thomson]. This alfalfa weevil parasite was recovered from the larvae of *Hypera postica* in Washington Co. (SC), for a new county record.

Bathyplectes curculionis [Thompson]. This alfalfa weevil parasite was recovered from the larvae of *Hypera postica* in Daviess (SW), Brown and Washington (SC), Owen (WC), and Morgan (C) Counties, all of which are new county records.

A hyperparasite (*Gelis* sp.) of *Bathyplectes curculionis* has been taken in rather large numbers (up to 1/sweep) in LaPorte Co. (NW), in what is probably a new county record.

Build-up of *B. anurus* has been very slow, and, south of US 50, *B. curculionis* parasitizes less than 10% of the population in most fields at least early in the season. North of US 50, up to 70-80% of the weevil population was parasitized by *B. curculionis* later in the season.

A wild bee (*Andrena wilkella* [Kirby]). An extensive nest site of this alfalfa pollinator expanded during the past 7 years. This year, after two days of heavy male emergence and activity, 4.5 inches of rain resulted in a cessation of male activity and no females emerged. The nest site has apparently been completely destroyed. (Warren Co. [WC]).

A European corn borer parasite (*Eriborus terebrans* [Gravenhorst]). Adults of this species were reared from pupae collected from the following counties: Jasper (NW), Marshall (NC), LaGrange and Noble (NE), all new county records. The Jasper County record was collected as an approximately 3rd instar larva of the European corn borer which was reared on artificial medium with the adult parasite appearing on August 2. The other three records were collected as pupae on July 18 from burrows of the corn borer.

A cereal leaf beetle parasite (*Tetrastichus julis* [Walker]). Cereal leaf beetle larvae parasitized by this species were released in the following counties in 1973: LaPorte, Porter, Lake, Starke (NW); Elkhart, St. Joseph, Marshall, Kosciusko, Fulton, Wabash, Miami (NC); DeKalb, Allen, Whitley (NE); Hancock, Rush (C); Wayne, Henry, Union, Fayette, Franklin (EC); Dearborn (SE). It was recovered from LaPorte Co. on June 6, a new county record (NW).

A cereal leaf beetle parasite (*Anaphes flavipes* [Förster]). This parasite was released in 1973 in the following counties: LaPorte, Porter, Lake, Starke, Jasper (NW); Wabash (NC); Noble, Whitley (NE); Rush, Decatur (C); Union (EC); Dearborn, Ohio, Switzerland, Jefferson (SE). It was recovered in the following counties, all new county records. (Date in June of recovery follows county name) St. Joseph (19), Fulton (13) (NC); Steuben (19), LaGrange (20), DeKalb (19), Allen (15) (NE); Wayne (12), Henry (11), Union (12) and Franklin (11) (EC).

A cereal leaf beetle parasite (*Diaparsis* sp.). Parasitized larvae of the cereal leaf beetle (1) containing this species, or adults (a) were released in the following counties during 1973 (where no letter follows the county, the release was by parasitized larvae): LaPorte, Porter, Lake, Starke, White (NW); Elkhart, St. Joseph, Marshall, Kosciusko, Fulton, Wabash, Miami, Carroll (NC); Steuben, DeKalb, Noble, Allen, Whitley (NE); Hancock, Rush (C); Wayne, Union (1 + a), Fayette (1 + a), Henry, Franklin (1 + a) (EC); Dearborn (a), Ohio (a), Switzerland (a) (SE). It was recovered during the year in LaPorte Co., for the second successive year.

A cereal leaf beetle parasite (*Lemophagus curtus* Townes). Cereal leaf beetle larvae parasitized by this species were released in LaPorte Co. (NW).

Parasitoids were supplied by Niles Laboratory, USDA, APHIS, and released by the State Entomologist and APHIS Plant Protection personnel. Parasitoid recovery survey was made by USDA, APHIS Niles Laboratory personnel.

GEOGRAPHY AND GEOLOGY

Chairman: ARTHUR MIRSKY, Department of Geology,
Indiana University, Indianapolis, Indiana 46202

ROBERT D. MILES, Department of Civil Engineering,
Purdue University, West Lafayette, Indiana 47907,
was elected Chairman for 1974

ABSTRACTS

Coal Mine Subsidence Problems in Indiana. RICHARD L. POWELL, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907. —The ultimate effect of abandoned underground coal mines in southwestern Indiana is progressive upward collapse and brecciation of the roof rock from the mine workings to the earth's surface. Such subsidence has caused differential settling and consequent fracturing of some buildings, houses, and other structures in several urban areas, and surface features such as "sinkholes" and trenches make some undeveloped real estate unsuitable for construction. Subsidence beneath highways has temporarily disrupted major transportation, water and utility lines.

The type of roof materials and overburden above the mined coal bed, the thickness of the overburden, the thickness of the mined seam, the size of the mined area, the types of roof support used during mining, and the time interval since abandonment determine the magnitude and extent of land subsidence.

Previous mine subsidence is most easily detected on conventional air photography, topographic maps or field investigation. Areas susceptible to future mine subsidence may be determined only by plotting the extent of underground mines from maps commonly on file in the individual County Recorder's offices or the Indiana Bureau of Mines. Nearly all of the available mine maps have been plotted on a county base preliminary coal map series published by the Indiana Geological Survey. However, not all mine maps are complete nor accurate.

Impact of Coal Mine-Waste Runoff on a Small Stream. PHILLIP M. CASEROTTI, Department of Geology, Indiana University, Bloomington, Indiana 47401, and GREGG MARLAND, Department of Geography-Geology, Indiana State University, Terre Haute, Indiana 47809. —West Little Sugar Creek drains an area of Vigo County, Indiana, which includes a major coal mine waste pile. Data show that the impact of the mine waste on the physico-chemical character of the stream is essentially unchanged 10 years after cessation of mining and is likely to continue indefinitely unless positive corrective measures are taken. Seepage from the pyrite-rich waste has been observed to contain as much as 200,000 parts per million dissolved sulfate and 56,000 ppm dissolved iron. Iron is precipitated as ferric hydroxides and dissolved oxygen and the pH recovers fairly rapidly with downstream distance and dilution. The adverse effects are more pronounced at low flow. By

the time the stream joins the Wabash River, some 11 kilometers from the waste pile, pH and dissolved oxygen have recovered to near normal values but the stream and stream sediments contain abundant ferric hydroxides.

Fossil Fuels and the Energy Crisis in Indiana. CHARLES E. WIER, Indiana Geological Survey, Bloomington, Indiana 47401.—The energy crisis will affect Indiana in much the same manner as it does the remainder of the United States. The State is now almost entirely dependent on the three fossil fuels: oil, natural gas, and coal. Although all three fuels are produced in the State, we import more than we produce. In 1972 we produced 24.5 million tons of coal, 6.2 million barrels of crude oil, and 640 million cubic feet of gas. We consumed nearly twice as much coal, 30 times as much oil, and 1000 times as much natural gas as we produced.

Known recoverable coal reserves will last about 300 years if production increases no faster than a few per cent per year. Petroleum produced at a slightly decreasing rate will last less than 10 years, and natural gas, assuming some effort to increase production, will last, perhaps, 20 years.

Reserves of coal occur in southwestern Indiana and the amount is fairly well documented. Additional exploration is not likely to increase reserves by more than 20 per cent. On the other hand, there are untested potential reservoirs that may contain significant new reserves of crude oil and natural gas in deeper rocks.

If Indiana tried to be self-sustaining in energy production, the fossil fuels would be consumed within two decades.

The Mineralogy and Geochemistry of Mercury Ore from the Senator Mine, Nevada, in the Light of Experimental Studies. NABIL Z. BOCTOR and GUNNAR KULLERUD, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.—At the Senator Mine, Nevada, a rather rare type of mercury mineralization is found. Cinnabar and metacinnabar occur together in barite veins transecting a granitic country rock. The mercury minerals are found mainly in the interstices of highly silicified fragmented barite as well as in quartz or chalcedony veinlets transecting the barite. The ore minerals are mainly metacinnabar and cinnabar which are associated with minor amounts of pyrite. Cinnabar occurs both as a primary mineral and as an inversion product of metacinnabar. Microprobe analysis shows that metacinnabar contains up to 4 weight per cent zinc and 2.5 weight per cent iron in solid solution. Metacinnabar in mercury ores associated with granitic intrusions is remarkably enriched in zinc compared to mercury ores of the serpentinite type where the concentration of zinc is < 0.01 weight per cent. Using the data of Barnes and Kullerud (1961) on the stability of sulfur containing aqueous species as function of f_{O_2} , f_{S_2} , and pH,

we can tentatively delineate the limits of the chemical environment during ore formation. The deposition of barite at the early stage of the mineralization indicates a high activity of the $SO_4^{=}$ species rela-

tive to the reduced sulfur species. The deposition of the sulfides at a later stage indicates a reduction of the sulfate by crossing the phase boundary between $\text{SO}_4^{=}$ and the reduced sulfur species to within or beyond the field in which barite is insoluble. The presence of pyrite and the absence of pyrrhotite in the ore stipulates a value of f_{S_2} greater than that which permits coexistence of the two minerals.

Formation of Silicious Stones: Agate. WILLIAM W. DAVIS, 4124 N. Pennsylvania Street, Indianapolis, Indiana 46205.—A procedure is described for examination of lap-polished sections of agates, jaspers, massive quartz crystals, and other silicious stones. Color and “topo” photographs provide a basis for examining structural detail on which an hypothesis is proposed for the conditions and sequence of events during formation and alterations of the stone.

Successive layers of silica, whether macrocrystalline quartz, chalcedony, or common opal (all of which may alternate repeatedly) are clearly distinguished. Influences of conditions such as the direction of gravity, quantity of solution, its composition and pH, and the temperature are discernible. The common elements and the variations in conditions and resulting structures in agates from around the world are illustrated photographically.

Masonry Materials in Historic Indiana Structures. JOHN B. PATTON, Indiana Geological Survey, Bloomington, Indiana 47401.—For authentic restoration or for acceptable renovation or alteration of historic structures, the exposed masonry materials must be identified, and the same or similar materials must be found.

Of the common masonry construction materials—stone, brick, mortar, and tile—only stone is used in its natural state. This may make the original sources easier to identify, but it poses difficulties when that source is no longer usable. The varieties of Indiana dimension stone extensively utilized have come from the stratigraphic units named Salem, Laurel, Mansfield, Liston Creek, and Ste. Genevieve. Much stone has been imported, but more for interiors or trim than as major exterior materials.

For many early structures, brick was burned at the construction site, and genuine duplication is nearly impossible. Even the commercially made brick of the pre-1890 period has no modern counterpart.

Early mortars can be readily imitated but rarely duplicated, as different constituents are used to attain similar appearance. Much of the tile used in historic buildings was obtained from outside the state. Few of the early varieties are obtainable now.

Techniques for identifying ceramic materials and mortar are not well developed, but microscopic examination and x-ray diffraction offer promising leads. Many early materials that would not meet modern specifications have splendid performance records.

What God and Man Have Wrought. TIM GOGNAT and STANLEY S. SHIMER, Science Teaching Center, Indiana State University, Terre Haute, Indiana

47809.—A blend of 2x2 slides and folk-rock music can be used in earth science classes to stimulate interest, raise questions and sensitize students to their environment. This teaching approach has been used to introduce units on astronomy, rocks and minerals, volcanoes, forms of erosion, mountain forms, fossils and meteorology. As a result of this innovative teaching strategy, college, high school, and middle school students have been inspired to explore further into earth science problems.

Preliminary Study of Interrelationships of Resistivity and Velocity in Indiana Lithologies. A. J. RUDMAN, M. E. BIGGS, R. F. BLAKELY and J. F. WHALEY, Indiana Geological Survey, Bloomington, Indiana 47401.

—Present knowledge of vertical seismic velocities in Indiana is based almost solely on acoustical transit times recorded on continuous velocity logs. Comparatively few wells have been logged for velocity, despite the importance of such data in seismic reflection prospecting for petroleum. Numerous wells in the state have been logged by electrical methods and the resistivity logs from these wells bear a close resemblance to the few available velocity logs. Using an empirically derived scale function which relates apparent resistivity and acoustical transit time, pseudo velocity logs that closely match real velocity logs have been generated from resistivity logs. Although the method shows promise for interpolating velocity information in local areas, the validity of a scale function over large geographic areas remains to be tested.

Should Indiana Be Prepared for a Shock? GERALD J. SHEA, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—Although Indiana is considered to be located in a non-destructive earthquake area, a total of 14 tremors have occurred in the past 100 years. Also, over 160 years ago a major earthquake affected our State, causing major damage, the full extent of which we can only guess. Should such an event occur again, is Indiana prepared for the shock?

By using differential analysis an interpretation of the strong motion seismograms, which were made by instruments located in Terre Haute, yield the following results: What moved 2 inches in 1968 probably moved 5 inches in the earth tremor of 1909 and as much as 13 inches in the earthquake of 1811. This deduction is interesting when you consider its relation to the trends in modern construction.

Multiple Tills at Wabash, Indiana. WILLIAM J. WAYNE, Department of Geology, University of Nebraska, Lincoln 68508.—Large till exposures are rare in northern Indiana, but a gravel pit at the south edge of Wabash has displayed as many as five separate till beds with intervening gravels and sands continuously for more than 25 years. The soft, clayey uppermost till of the Lagro Formation represents the most recent advance of Erie Lobe ice; it overlies a gravelly sand outwash. Three very compact sandy silty gray tills, each distinctive in color and composition, underlie this sandy outwash and are underlain by a thick gravel unit that coarsens upward. A boulder pavement caps the middle

till, which is stonier than the tills that sandwich it. Beneath the coarse gravel at the north end of the pit is a silty till that is reddish brown (5YR 5/4 to 7.5YR 5/4). No buried weathering profiles were observed on any of the tills or gravels. The triple till unit undoubtedly is the Trafalgar Formation (Wisconsinan). No records of a reddish brown till exist for northeastern Indiana, although a till of somewhat similar color in Warren County may be part of the Jessup Formation. It would seem reasonable at this time, then, to include this unusual till in the Jessup Formation and to regard it as Illinoian in age.

Fracture Analysis of the Kentland, Indiana, Disturbance. HEATHER COLLINS, Department of Earth Sciences, Washington University, St. Louis, Missouri, and L. A. BROWN, Department of Geosciences, Purdue University, West Lafayette, Indiana 47907.—A survey of joints in the McCray quarry exposing the Kentland cryptoexplosion structure in Northern Indiana revealed a systematic pattern. An equal-area plot of joint poles indicated three major joint sets. Two of these sets were nearly at right angles to the fold axis and the third, nearly parallel to the fold axis. An equal area net of poles of bedding planes showed the fold axis to be plunging 58° N 16° W. A paired diagonal joint set to the fold axis was not readily discernible. Joint spacings recorded at the quarry fall within the range of 0.5 to 3.0 feet with a peak spacing concentration occurring at 1.0 feet. Bedding planes generally are spaced less than 5 feet apart.

A comparison between the Kentland disturbance and other similar type structures, presence of coesite in trace amounts in the St. Peter Sandstone, high pressures developed by normal geological processes and by explosives used in the quarrying operation lead us to question the popular meteorite-impact origin for the disturbance. Until more information is available, the Kentland disturbance will have to remain classified as a cryptoexplosion structure.

A Meso-Scale Analysis of the Journey to Work: The Example of the Burley Tobacco Farmer

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Abstract

The 24 Burley tobacco allotment farms located in the corn belt of Indiana were analyzed according to their spatial efficiency, based on the distance the three work places were from the farmhouse, the source of labor. In most instances, they were located farther apart than was necessary. Most of the growers were "gentlemen farmers" and could not be expected to be efficient managers of their resources. Only four of the growers consciously located them near the house, to conserve time and energy.

Introduction

This investigation of the spatial arrangement of tobacco farming work places is based on von Thünen's *Isolated State*: "How does the distance between plot and farmstead affect labor costs?" (1). von Thünen observed that various types of farm labor were necessary to produce certain crops, and that each group of tasks were generally performed in certain locations. In his analysis of work and the work place, he was primarily concerned with "labor whose amount depends entirely on distance, such as manure carting or bringing in the harvest". He indicated that the shorter the distance travelled from the farmstead to the "plot", the less time consumed in this endeavor; and, therefore, the more time that would be available for other chores.

Burley tobacco production is a labor intensive crop. A typical half acre allotment is characterized by five basic phases. The first consists of approximately 30 days of care while the seedlings sprout and mature in the seed bed, followed by a day or two of transplanting the seedlings. This is followed by about 90 days of checking the growing crop in the field. Several days are involved with harvesting the crop. Finally, about 30 days of checking the curing leaf in the barn must be done. Trips must also be made between each work place and the farmhouse, the source of labor. It is a "13-month-a-year" endeavor more suitable to small, labor intensive farms than to large extensive farms (2).

This study is concerned with the farmers who grow Burley tobacco and are situated on the extreme northern margins of the "Burley Belt", namely those 24 allotments that are located within the "Corn Belt" region of North America, as it is defined by Baker (3) (Fig. 1). According to Hart, the arrangement of farmsteads and field patterns in Indiana is associated with increasing farm size and the requirement for increased capital investment in land and machinery (4). His study also indicates that larger farms are becoming the norm. It also shows that small inefficient farms are being combined into larger farms, operated by more skilled and efficient managers. This researcher hypothesized that these "corn belt" tobacco farmers were good man-

agers and would arrange the seed bed and "patch" in a way so as to minimize the distance and thus travel time between each of them, and the farmhouse, and the curing barn.

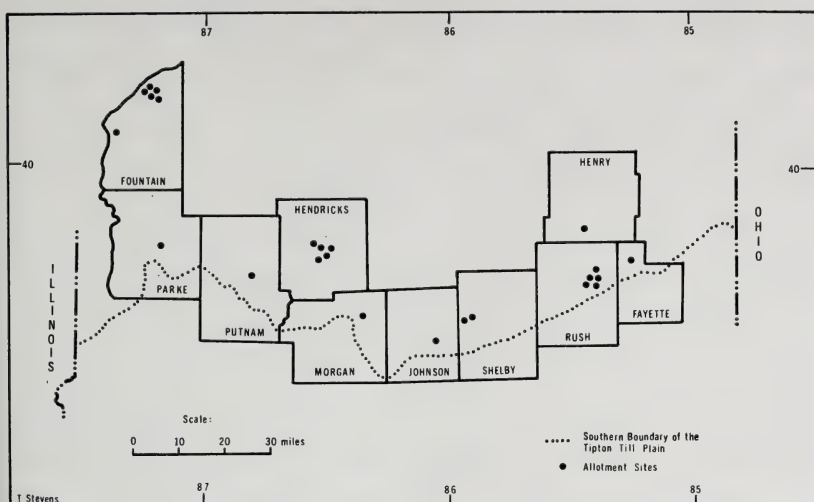


FIGURE 1. Location of the Burley tobacco farms within the Tipton Till Plain in Central Indiana.

Background

Johann Heinrich von Thünen was one of the first to investigate the spatial arrangement of agricultural production locations and propose a rationale to determine why certain crops were produced in certain locations (1). von Thünen's estate in extreme Northern Germany was 1,000 acres in size, arranged in an irregular layout. The mean distance between the farmstead and the various plots was 3,464 feet. He observed that it took laborers 32 min to make a one-way "journey to work" of 3,464 feet. This rate of movement is equal to 0.82 mph. von Thünen was concerned with "how will labour costs change with a change of distance" and "what portion of these costs will remain where the distance between plot and farmstead is equal to zero?"

TABLE 1. Interrelationships between tobacco production work places.

Trips Between	Reason for the Trip	Number of Trips
House and Bed	Daily care and inspection	30
Bed and Field	Transplant seedlings	3
House and Field	Daily care and inspection	90
Barn and Field	Hauling the harvest to the barn	10
House and Barn	Daily care of the curing leaf, and stripping and sorting the cured leaf	40
Total Trips		173

Time spent in travel to and from the work place is usually considered to be indirect labor and is not directly productive as is the action of transporting the harvest to the market. The relative efficiency of each tobacco grower within the study region was thought to be rateable according to the following criteria: the closer the work places are to the house, the source of manpower, the more efficient the producer could be said to be. The logic behind this criterion is that ideally, (because of soil preparation methods), the plant bed and field can and should be located on the best possible land as close to each other and to the farmhouse as is physically possible. This should be done because these two work place locations must be visited each day to care for and inspect the plants. The closer the work places (barn, plant bed, field) are to each other, the less time and effort that will have to be expended in travel between the house and each work place (Table 1). According to a hypothesis proposed by Ratcliff, the best possible arrangement of these three work places and the farmhouse would be for all four of them to occupy the same place (5). Since this is obviously impossible, the next best arrangement, and thus the optimum, or the most practical, would be for all four of them to be located adjacent to each other in four quadrants of a regular polygon, or zero distance apart (Fig. 2). If allotment regulations would permit, the worst arrangement would be one in which all four work places are located at such a large distance apart, that all of the 2,000 available working man-hours per year, (40 hours/week X 50 weeks = 2,000 man-hours/year) would be consumed in travel; and, thus, no tobacco could be grown. The foregoing rationale sets up the basis for ranking these growers according to a space-time utility criterion.

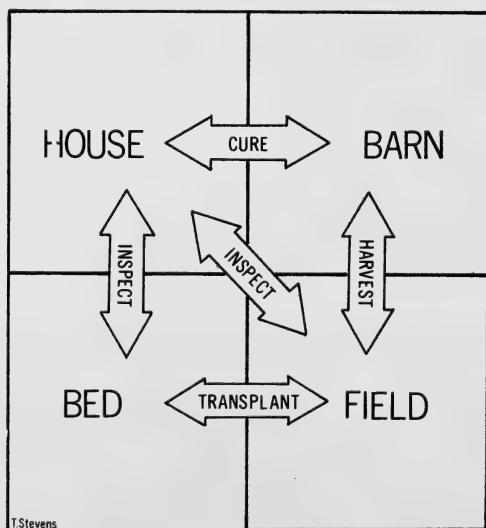


FIGURE 2. Optimum spatial arrangement of tobacco farm work places. Note the reasons for the journeys between each work place. All of these activity locations are closely interrelated, except for the plant bed and the barn; there is no need for direct travel between them.

A further refinement can be added to this analysis based on a proposal by Simon who wrote that "the human response to a specific set of circumstances can be described as a continuum from optimization to the minimum condition attainable, which will allow the producer to survive in the market place" (6). According to him, "Economic man has a position at one extreme of the continuum" and, ". . . the existence of a continuum provides an opportunity to explore the problem of determining the relative position of individuals on its scale."

The efficiency of the growers was determined by the total distance (in feet) each work place was from the other multiplied by the number of trips that must be made during the course of the year, ranked according to importance. In the case of Burley tobacco production, the house-field distance is the most important, since it must occur at least 90 times during the growing season. In decreasing order of importance are the house-bed distance with 30 trips, the house-barn with about 10; and least in importance, is the field-bed distance since it requires only about three trips to produce a typical half-acre allotment (Table 2).

TABLE 2. *Distances the three work-place locations are from the farmhouse and each other.*

Site Identi- fication	Distance ¹					Total
	House to Field	House to Barn	Bed to Field	Barn to Field	House to Bed	
A	16874	180	16934	16925	360	51273
B	1750	1200	380	460	1800	5590
C	50	75	130	150	30	435
D	280	220	130	10	370	1010
E	300	150	240	250	190	1130
F	130	150	0	50	160	490
G	400	220	410	620	175	1825
H	320	200	375	100	75	1070
I	150	250	0	240	0	640
J	800	400	940	380	120	2640
K	30	175	260	80	360	905
L	240	120	150	50	185	745
M	10428	200	10428	10428	100	31584
N	230	570	10	620	300	1730
O	30	110	0	80	0	200
P	380	180	0	425	380	1365
Total	32392	4400	30387	30868	4605	102652
Simple						
Average	2024	275	1899	1929	287	6415
Adjusted						
Average	363	275	216	251	287	1413

¹ Distances are line of sight and were measured in feet. Sites A and M are simple average distances for multiple allotment arrangements.

Analysis

To facilitate the analysis, the distances presented in Table 2 are for one-way trips only. Site "O" appears to be the most "efficient",

since the distance from the house to the plant-bed and plant-bed to field was zero. However, the distance actually amounted to a round trip journey by truck of 6 hours for the grower to purchase his tobacco seedling transplants from a grower who was located in Kentucky. In two instances (Sites A and M), several nearby Burley allotments were being cared for by one man; and in one of these situations, by a person other than the owner of an allotment. If these two individuals did not grow the tobacco, the allotments would fall into disuse and be discontinued by the ASCS office. With this rationale, these two arrangements were considered as one allotment. In both of these cases, the tobacco growers paid cash rent for the allotment acreage.

TABLE 3. *Total mileage rank order array for 16 tobacco growers.*

Rank	Site	House Field	House Barn	Bed Field	Barn Field	House Bed	One Way Total	Farm Size
1	O	.51	.83	—	.15	—	1.49	9
2	C	.85	.57	.07	.28	.17	1.94	47
3	K	.51	1.32	.14	.15	2.04	4.16	10
4	F	2.22	1.14	—	.09	.91	4.36	52
5	I	2.56	1.89	—	.49	—	4.90	63
6	L	4.09	.91	.08	.09	1.05	6.22	510
7	H	5.45	1.52	.21	.19	.43	7.89	370
8	E	5.11	1.14	.14	.47	1.08	7.94	320
9	D	4.77	1.67	.07	.02	2.10	8.63	400
10	P	6.48	1.36	—	.80	2.16	10.80	120
11	G	6.82	1.67	.23	1.17	.99	10.88	300
12	N	3.92	4.32	.01	1.17	1.70	11.12	356
13	J	13.64	3.03	.53	.72	.68	18.60	536
14	B	29.83	9.09	.22	.87	10.23	50.24	170
15	M	177.75	1.52	5.92	19.75	.57	204.94	310
16	A	287.62	1.36	9.62	32.05	2.04	232.69	6
Total		552.14	33.33	17.26	58.46	26.16	588.36	3579.00
Average		34.51	2.08	1.08	3.65	1.64	43.02	223.69
Adjusted Average		6.63	2.27	1.60	.50	1.96	11.36	250.31

¹ Less sites A, M and O.

The 24 allotments individually ranged in size from 0.16 acres to 1.39 acres. However, when they were grouped as 16 allotments, they ranged in size from 0.22 acres to 3.04 acres. In this latter array, the median size was 0.50 acres, the mean, 0.93 acres, and the mode was 0.50 acres.

Only 2 of the 16 farms in this study were large-scale farm operations (over 500 acres). Only 2 of the remaining 14 growers depended on tobacco as their prime source of cash income. The remainder of these operations were maintained by "gentlemen farmers" who grew tobacco primarily because they enjoyed the activity.

Conclusions

Most of the tobacco growers were "gentlemen farmers" who work in nearby cities and live on small farms and raise tobacco because an allotment to grow and market tobacco went with the land when they

purchased it. These men consider this usually unpleasant series of tasks to be a profitable hobby. Therefore, they do not take into account the distance involved and the associated amount of time since this agricultural activity is merely a sideline. The most obvious constraint on time and distance travelled is that the shortest distance and therefore the least total time involved is related to the size of the farm in acres. The smaller the farm, the shorter the distance.

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The Universal Transverse Mercator Grid

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Abstract

Recent developments in land-use planning require a complete description of the incidence, distribution and relationship of phenomena. To solve problems it is necessary to determine what exists and where it exists.

To provide an accurate base for coding data and a compatible format the Universal Transverse Mercator grid (UTM) and the Transverse Mercator projection (TM) should be used to code data needed for planning. This paper examined the advantages of the UTM as the proper grid system for coding compatible data for local or national land-use surveys.

Introduction

The first step in land-use planning is a descriptive categorization and recording of the extent, density and dynamic relationships of phenomena. An inventory of land-uses for planning purposes presents a major problem due to the large amounts of data that are collected. Such data must be compatible not only to the procedures used in collection and recording but also to computer software application for manipulation, storage and retrieval. Intelligent land-use planning requires the selection of a method by which large amounts of data can be identified, recorded and made available for immediate retrieval.

The best method for identifying and recording data is the Transverse Mercator projection (TM) used in combination with the Universal Transverse Mercator grid (UTM). The UTM is a combination of rectangular coordinates and graticule that has a number of desirable characteristics for inventorying large amounts of data.

The purpose of this paper is to reintroduce the UTM system and to promote its acceptance as the proper method for encoding data for land-use planning.

Discussion

The UTM system as presently used has been designed to represent the earth's surface between 84° N latitude and 80° S latitude.

Transverse Mercator Projection

One major part of the UTM system is the Transverse Mercator projection (TM). This projection is the transverse case of the Mercator projection (Fig. 1). Dashed lines on Figure 1 indicate the Mercator projection while the solid lines indicate the superposition of the Transverse Mercator. It can be seen that a great circle of longitude of the Transverse Mercator occupies the parallel of 0° latitude of the Mercator thus a rotation of 90°. Hence the poles of the transverse case are located along the equator of the Mercator. Consequently, the equator of the transverse case (shown thrice) is coincident with a meridian of the Mercator.

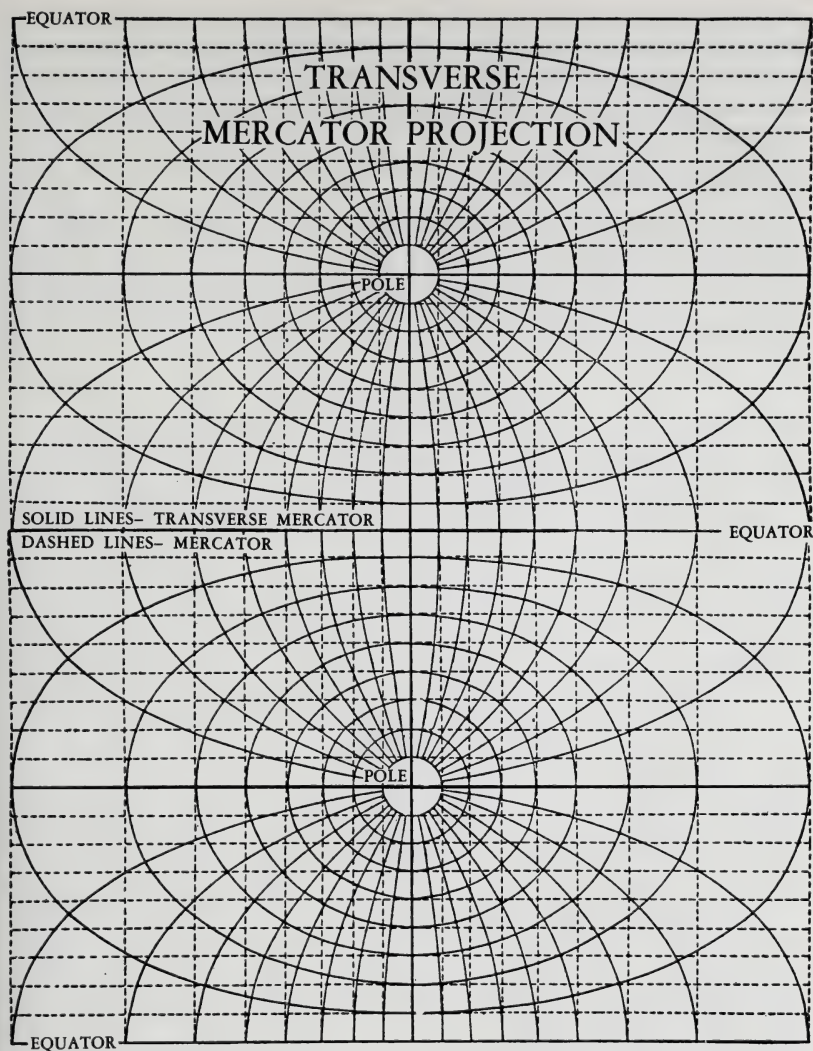


FIGURE 1. The Transverse Mercator Projection (solid lines) as it appears relative to the Mercator projection (dashed lines). Adapted from *Elements of Map Projection*, page 123

A modification in using the Transverse Mercator increases its usefulness. Again reference to Figure 1 indicates that along the central meridian of the TM exact scale is held. Modification of this situation occurs as scale is held exact "along two small circles formed by planes parallel to the plane of the central meridian" (3). In reality therefore, the projection is derived from the secant position. This situation allows true scale along parallel lines located equidistant from the central meridian of the projection. The surface distance referenced between lines of true scale is 360 km (360,000 m).

Only a narrow extent of 3°.5 on either side of the central meridian is actually used in conjunction with the UTM grid. Logically the total system is not used for large-scale mapping purposes. The meridians and parallels of the projection to be used are identified according to that portion of the earth to be mapped.

Universal Transverse Mercator Grid

The Universal Transverse Mercator grid (UTM) is a system of intersecting parallel lines forming a series of rectangles (Fig. 2). The dimensions of each rectangle can be determined according to the degree of complexity required as subdividing each square results in setting off smaller areas.

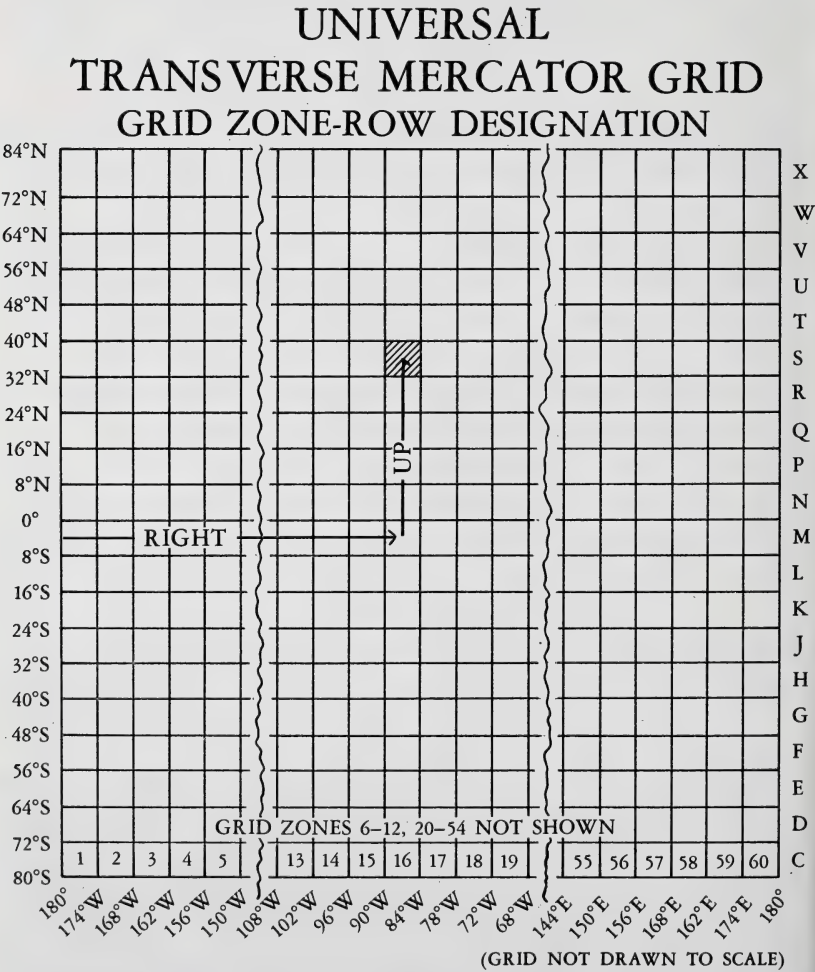


FIGURE 2. Grid zone identification of the Universal Transverse Mercator grid.

The grid is located on the earth's surface such that a vertical zone is centered on a chosen central meridian of longitude and rows are centered on the equator. Each vertical zone at the equator is 6° of longitude in width and extends from 84° N to 80° S (as presently used). Figure 2 indicates how each zone is set off and identified. Sixty zones are numbered consecutively eastward through 360° with Zone 1 at 180° .

With one exception the vertical zones are delimited into rows 8° wide. Again, Figure 2 locates the rows and the method of identification. Successive rows are lettered C to X (omitting I and O) beginning at 80° S and extending to 84° N. The resultant grid consists of rectangles bounded by parallel lines equally spaced with a peculiar location.

The identification of each rectangle at various levels is simple and straightforward. All 6° by 8° rectangles are identified by zone-row designation. Figure 2 indicates the location of one such area as 16S. Further subdivisions are based upon a method of "false eastings" and "false northings" (Fig. 3). Using the intersection of the central meridian of each vertical zone and the equator an origin is established so that each area subsequently located always has a positive listing. The central meridian is identified as 500,000 m east while the equator of even-numbered zones is begun at 500,000 m north. Odd-numbered zones begin at 0 m north. Proceeding in the southern hemisphere is such that the equator is enumerated as 10,000,000 m north (4).

Figure 3 shows how each zone and row is further subdivided into 100,000 m squares. The alphabet is used to subdivide the 6° column into 100,000 m columns. Beginning at 180° longitude and proceeding eastward each 100,000 m column is identified A-Z (excluding I and O). For each 18° of longitude the alphabet is repeated. Similarly rows are created using the alphabet A-V (again excluding I and O) south to north and is repeated at 2,000,000 m intervals. Each 100,000-m square is thus identified by two letters. Further subdivision to the 10,000 m, the 1,000 m and the 100-m square is accomplished by equal divisions of each square. Thus 10,000-m squares are designated by two 1 digit numbers derived from the false eastings and northings. Subsequent divisions to the 1,000 m (km) uses two 2 digit numbers and the 100-m square (hectare) uses two 3 digit numbers.

An example is as follows (Fig. 4):

- 16S locates a 6° by 8° area in Indiana and Illinois
- 16SDD locates the 100,000-m square in which Terre Haute is located
- 16SDD66 locates the 10,000-m square in which the Vigo County courthouse is located
- 16SDD6363 locates the 1,000-m square in which the Vigo County courthouse is more precisely located
- 16SDD633635 locates a 100-m square within the area occupied by the Vigo County courthouse

the real earth figure, but to be of practical use the ellipsoid of revolution appears to be as complicated a figure as is warranted" (2). Since much of the mapping on the earth's surface is large-scale mapping there is an advantage to reducing the sea-level arc to a plane surface. This changes spherical coordinates to rectangular coordinates thus

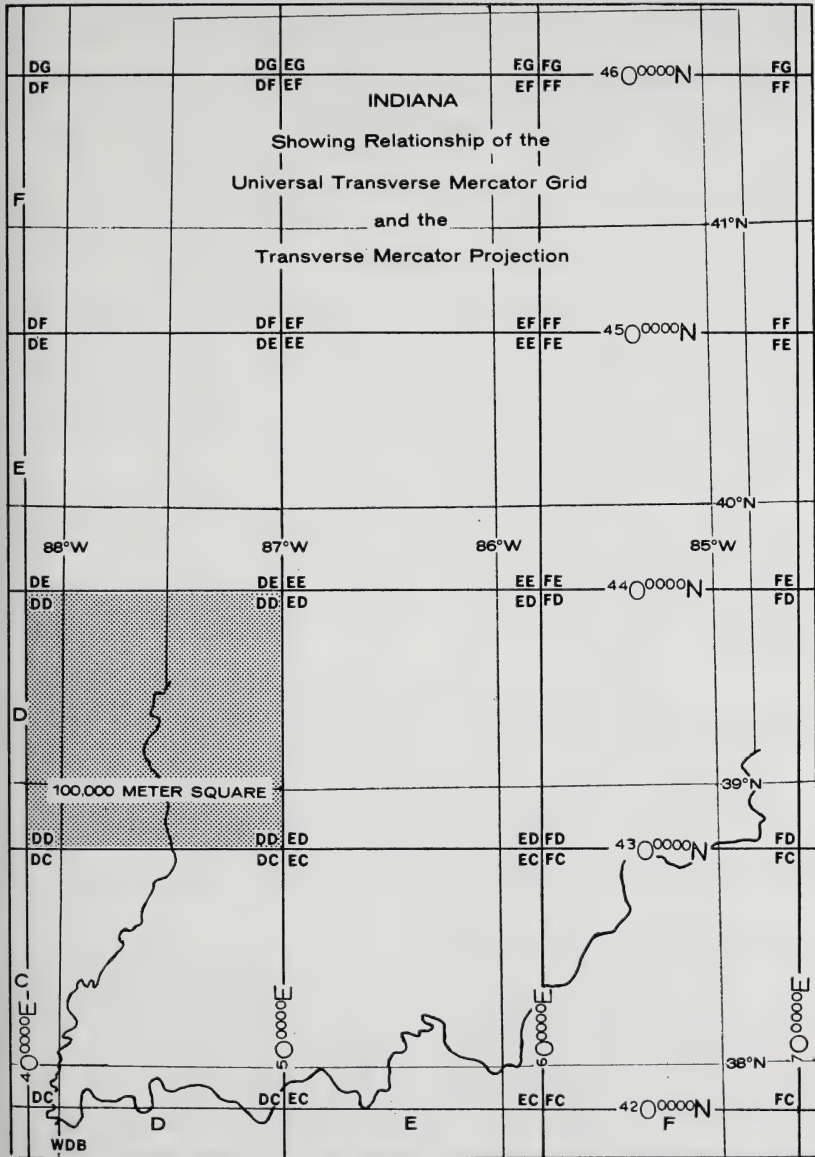


FIGURE 4. Indiana showing relationship of the Universal Transverse Mercator grid and the Transverse Mercator projection.

reducing to a minimum alteration from true scale representation. Furthermore, the transformation promotes ease in determining distance and azimuth and it also will allow all present maps to be recast to a compatible identification format.

The transformation from spherical coordinates to rectangular coordinates allows for a minimum scale alteration. Large-scale mapping and surveying involves the use of rectangular coordinates and it is the "consensus of those who have seriously considered the fundamental mapping problem (that) . . . a series of cylinders transverse to the equator are the best surfaces to be used and that the projection should be conformal" (1). The Transverse Mercator is conformal on a transverse cylinder. Conformality as a property requires that all angular relations be preserved and also scale in all directions from a point be true. More importantly with the Transverse Mercator the scale factor resulting from points on the sea level arc being projected to the plane surface would range from 0.99960000 through unity to 1.0016504. The angle from the central meridian in each grid zone is $3^{\circ} 40'$ for the latter figure. Furthermore, the elevation of the datum would range from a minus 2,548 m at the C.M. through 0 to a plus 10,516 m at the edges of the grid zone. These figures are for a 6° width zone and it is obvious that 4° or 2° width zone would reduce scale alteration even more. These scale factors represent tolerable error for most mapping and surveying projects.

Calculation for distance and azimuth between points is reasonably simple with the UTM grid. Since the coordinate system is based on a known projection the relationship or scale distortion can be correctly established for all points. These factors can be readily applied as to bring all computations within geodetic accuracy (3). Measured angles originally referred to the spheroid can be reduced to the plane surface by the (t-T) correction.

A reference system based on the UTM would allow compatible mapping projects between discontinuous areas. If selected the UTM could be related to a single earth-centered-reference-system. All calculations from ground inventory reduced first to sea level and then to the reference datum would insure not only compatible mapping between locales, even on a world-wide basis, but also insure compatible mapping between projects initiated by various agencies. Geodetic control on ground location would be the same for all mapping projects.

Requirements of Data Encoding

Requirements of data encoding and subsequent computer application produces constraints on any data encoding system which must be compromised. The UTM grid system offers a method to permit data to be recorded on a common base, provides for maximum data content and allows for up-to-date base maps on a continued basis.

The effectiveness of any inventory system is enhanced if all data can be recorded on a common base. The UTM grid system provides through intersecting parallel lines either the 1,000-m square or the 100-m square as the basic unit within which all categories of data can be

referenced in the metric system. Using proper computer software many categorically different data can be assigned the same location coordinates. It is standard procedure in computer mapping for grids to overlay source maps from which x, y, z coordinates can be easily digitized. A common grid would permit interagency compatible data banks and reduce the considerable amount of duplicate effort. The identification of a proper landscape unit from which to inventory data is a key point in an approach to land-use planning (5).

The selection of a common base coupled with appropriate computer software provides for maximum data bank content. A proper land-use inventory must be so organized that collected data can be used to provide maximum interpretation of land-uses although maximum interpretive ability can occur only if software allows a selectivity in informational detail retrieval.

Recent events in Congress portend the advent of federal level mandates regarding land-uses and land-use planning. Because of this it is imperative that any attempt at inventory should be done so that data banks are available on an interagency basis. This capability will be achieved only if all data are collected in a compatible format. The United States Geological Survey has for many years produced topographic sheets with the UTM grid ticks and presently are producing sheets with a fine line UTM grid superimposed. But some state, regional and federal agencies are compiling detailed data bases "independently and without coordination, with resultant duplication of effort and establishment of information systems that are not compatible" (5). The need for standardized collection of data that is compatible between locales, agencies and even other countries can begin with the acceptance of the UTM grid system.

Conclusions

The UTM is a system retaining the necessary requisites for a proper reference system. They include:

- 1) The system is conformal allowing true scale and preservation of all angular relationships about a point.
- 2) With a superpositioning of a grid small scale alterations are maintained.
- 3) With the superpositioning of a grid a common base for data diversity categorization is provided at either a square kilometer or hectare size.
- 4) The use of the UTM grid would allow compatible data banks as they would be based on the same measurement system.
- 5) Referencing in the metric system would simplify data encoding and would permit interface with extracontinental mapping.

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Urban Land Use Identification in the Gary-Hammond Area by Computer Analysis of Multispectral Satellite Data

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Abstract

Multispectral scanner data collected over the southern part of Lake Michigan by the first Earth Resources Technology Satellite (ERTS-1) were analyzed to assess the utility of computer-implemented classification of urban land uses. Northern Lake County, Indiana (Gary-Hammond area) was selected as the study site because of the diversity of land uses, concentrations of population, and heavy industry in this area. The resulting classification indicated that important categories of urban land use, such as commercial/industrial areas, older (higher density), and newer (low density) housing could be identified, as well as woodland areas, agricultural land, water, and smoke emissions (along the coastal areas). This study indicates that computer analysis of ERTS multispectral scanner data can be a valuable input to the urban-regional planner. Not only can ERTS data be a source of land use information, but it can be used to update and/or supplement existing land use data.

Introduction

The compilation of data of large metropolitan areas by land use planning officials is presently a very time consuming process. Inventories of such diverse areas may take several years and are often obsolete by the time they are completed.

A more rapid means of data collection is available through use of an orbiting satellite. NASA's Earth Resources Technology Satellite (ERTS), launched on 23 July 1972, offers this opportunity for land use surveys, and, because the satellite passes over any given area once every 18 days, it may also be used to monitor continuously land use changes.

The objectives of this study were to map gross land uses in the highly populated, industrialized Gary-Hammond area using multispectral data collected by ERTS, and to determine the feasibility of land use classification by this method.

Background and Study Area

Multispectral scanner data collected by ERTS may be analyzed by two methods. In the first, or pictorial approach, the analyst observes differences in gray levels in the imagery reproduced from digital tapes onto a video monitor and black and white photographs. The analyst either studies the four band images separately (band 4, 0.5-0.6 μ m; Band 5, 0.6-0.7 μ m; Band 6, 0.7-0.8 μ m; Band 7, 0.8-1.1 μ m), or

agricultural land, forested areas, and bodies of water. Data were collected from the 1 October 1972 ERTS pass, a cloud free day. The four ERTS bands were examined pictorially and several areas were selected from these images for land use classification by cluster analysis.

Results and Discussion

Figure 2 compares the display imagery from two bands (images A and B; D and E) with imagery from digital analysis of the data (images C; F) for the Gary-Hammond area. Images A, B, and C each show the entire study area [54×46 km (34×29 miles)]. Enlargement of the northwestern portion of each of these three images is shown in D, E, and F, respectively [areas measure 27×23 km (17×14.5 miles)]. The horizontal scale for each image in Figure 2 is approximately three-fourths that of the vertical scale and the true north-south line is rotated approximately 14° counterclockwise to vertical.

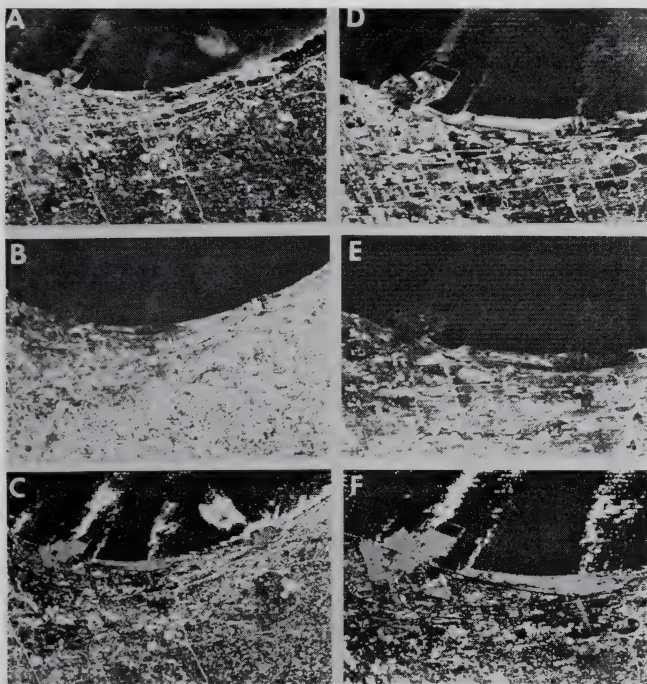


FIGURE 2. Photos showing relationship between pictorial and digitally analyzed imagery for land use classification. Image A is Band 4, 0.5-0.6 μ m; B is Band 6, 0.7-0.8 μ m; C is a computer-implemented classification of the study area. Images in A, B, and C show the entire study area; enlargements of the northwestern portions of those three images are shown in D, E, and F, respectively.

The land classification scheme was developed with imagery from digital analysis. Five gray levels used for the display of the spectral classes were as follows:

Medium Gray	Industrial/Commercial
Black	Older Housing; Water
White	Newer Housing; Smoke
Light Gray	Trees
Dark Gray	Grassy (open, agricultural)

The resulting computer-implemented land use classes are found in Figure 3.

Industrial/commercial areas are shown as medium gray and are characterized by the occurrence of rooftops, parking lots, streets, and

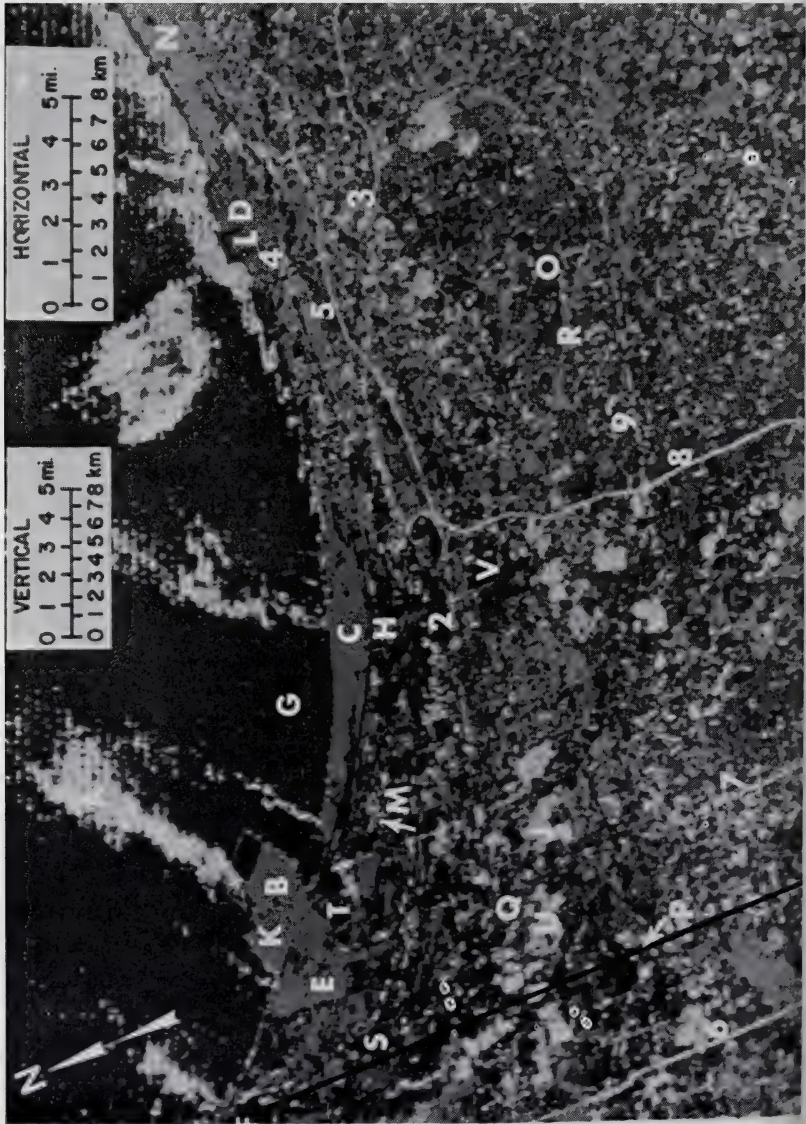


FIGURE 3. *Computer-implemented land use classification of Gary-Hammond area. Letters or numbers refer to the following:*¹ White letter or number indicated in Figure 3.² Features of interest and land uses are indicated by letters; highways are indicated by numbers.³ Five spectral categories of commercial/industrial land use were used in the classification scheme.

L ¹	Feature, land use, or highway ²	Spectral class ³
A	Smoke plume	smoke
B	Inland Steel	commercial/industrial
C	United States Steel	commercial/industrial
D	Bethlehem Steel	commercial/industrial
E	Oil Refineries	commercial/industrial
F	Wolf Lake	water
G	Lake Michigan	water
H	Gary-Central Business District	commercial/industrial
J	Highland-subdivision	newer housing
K	Indiana Harbor	commercial/industrial
L	Port of Indiana	newer housing
M	Gary Municipal Airport	wooded
N	Indiana Dunes States Park	grassy/agricultural
O	Agricultural area	-----
P	Indiana Illinois State Line	grassy/agricultural
Q	Wicker Memorial Park	wooded
R	Trees along Deep River	older housing
S	Hammond-residential area	older housing
T	East Chicago-residential area	newer housing
U	Munster-subdivision	older housing
V	Gary-residential area	newer housing
2	Interstate Highway 80-94	newer housing
3	Interstate Highway 80-90	newer housing
4	U.S. Highway 12	newer housing
5	Interstate highway 94	newer housing
6	Illinois highway 394	newer housing
7	U.S. Highway 41	newer housing
8	Interstate Highway 65	newer housing
9	U.S. Highway 30	newer housing

bare ground. They are usually void of vegetation. Examples include Inland Steel, U.S. Steel, Bethlehem Steel, and the Gary-Central Business District.

Older Housing, displayed as black, consists of areas developed prior to World War II in Hammond, East Chicago, and Gary. Closely spaced rooftops along with mature vegetation (large trees) are the reasons for the spectral separability of this class. Water has been assigned the same gray level as older housing (black) and, considering the distribution of each, prevents confusion between the two. Water is largely restricted to Lake Michigan and other water bodies such as Wolf Lake. The older housing is located between the coastal industrial establishments and newer housing.

Newer housing developments, shown as white, are located on the fringes of the urbanized area in the municipalities of Munster and Highland. The majority of the structures were built after World War II. Since lawns and streets were also primary constituents of this spectral class, four-lane highways are placed in this category. Smoke was assigned the same gray level as newer housing (white) but is found only over Lake Michigan while newer housing is located to the south.

Wooded areas, shown as light gray, are commonly associated with the drainage pattern of the study area. Principal locations of trees appeared in conjunction with the Deep River and the dunes park area along Lake Michigan.

An agricultural class, displayed as dark gray, was identified in the southern part of the study area. This class included cropland, pasture, and idle land in rural areas, as well as parks, golf courses, and open land in urban zones.

The land use classes identified in this study correspond well with the classes proposed by Anderson *et al.* (1), and with those developed in other ERTS urban analyses (3, 5, 7, 9, 10). Further investigations were made of industrial areas in this analysis because they constitute a large part of the Gary-Hammond complex.

For the analysis of commercial/industrial land use, the northern part of the study area was used (Fig. 1). Spectral classes were displayed using the following five gray levels:

Black	Rooftops (dark reflectance)
Dark Gray	Rooftops (bright reflectance)
Medium Gray	Gravel-Sandy Areas (3 classes)
White	Smoke
Light Gray	All Other Classes

The resultant classification image is shown in Figure 4. This is similar to the classification scheme used in Figure 3, the only difference being the assignment of gray levels to the spectral classes.

The class shown as black in Figure 4 is associated primarily with dark roofing material and large coal piles. Large areas of this spectral class are associated with the three large steel firms located here.

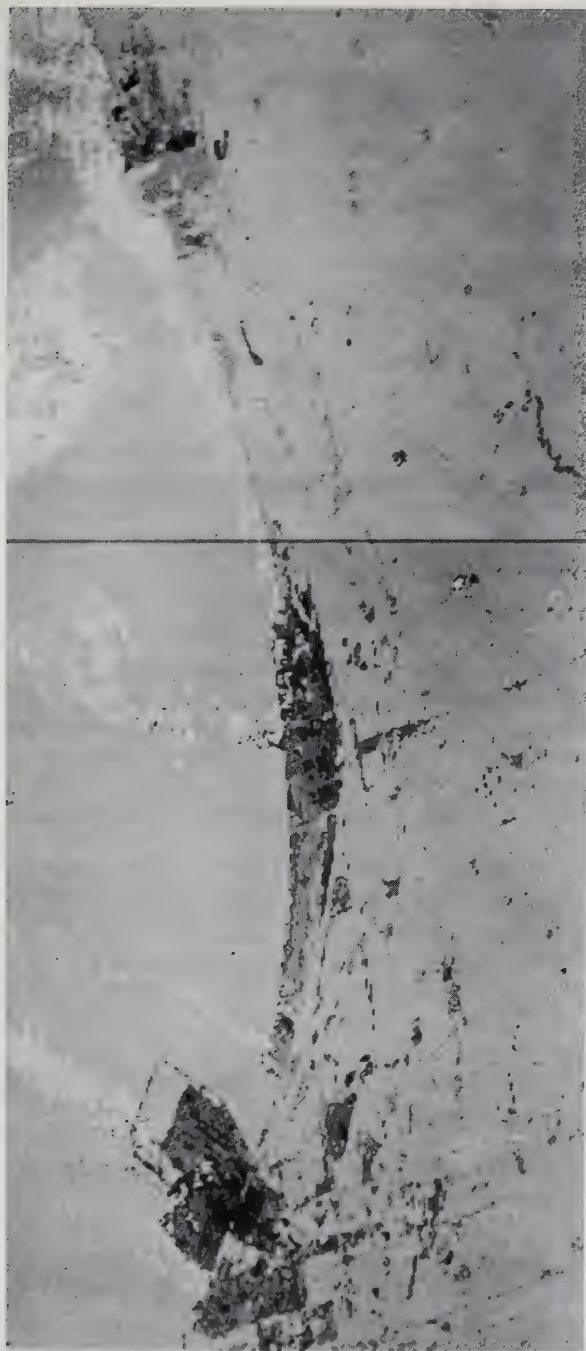


FIGURE 4. Photo from digital display of computer-implemented land use classification of Gary-Hammond area (northern part of study area). Classes represented: dark roofing material—black; lighter-colored roofing material—dark gray; gravel/sandy areas—medium gray; smoke—white; all other spectral classes—light gray.

The other rooftop class, displayed as dark gray, is associated with brighter reflecting rooftops. Reasons for the three spectral categories of gravel/sand (all displayed as medium gray) are not clear at this time, but they are presumably related to both the color of the material and the presence or lack of sparse vegetative cover. Two large sites of gravel/sand material are located to the northwest: 1) between the large building complexes of Inland Steel and U.S. Steel companies and 2) in the large oil refining district in East Chicago. To the northeast, another large gravel/sand deposit is located west of the buildings of Bethlehem Steel. This area was dominated by one of the three classes of gravel/sand, and had a particularly high spectral reflectance in all bands of the spectrum. The ground cover is dune sand, typical of this locale.

The final class shown in the classification scheme (the white areas in Lake Michigan) is speculated to be smoke coming from coastal industrial establishments. Several facts support a conclusion of presence of smoke. The linear, parallel arrangements of the data points, extending some 50 km into Lake Michigan, are contrary to the circulation patterns in the Lake. Moreover, meteorological records report that the wind was out of the southwest on the morning of the ERTS pass.

While smoke was identified in the western part of the study area, the smoke data points along the eastern lake shore were probably water. Spectrally, this class is similar to water, having a very dark reflectance in Band 6 (Fig. 2-B). The large area classified as smoke northwest of Bethlehem Steel is assumed to be a thin cloud cover. Despite the spectral confusion, the partial separability does warrant further investigation of the phenomenon of smoke located over water bodies.

Classification Accuracy

An attempt was made to determine the classification accuracy of this study by selecting a number of test sites for each land use and determining the class accuracy (Table 1). Water, woods, older housing, and newer housing were all identified with over 90% accuracy. Difficulty was encountered in identifying properly industrial/commercial areas, most of the misclassification being attributed to older housing. The poorest classification accuracy was in grassy agricultural areas, where less than 70% of the data points were accurately classified. Misclassification of these areas was of two major types: 1) agricultural regions associated with darker colored soils which proved difficult to separate from older housing (one such area was located in Munster and Highland), and 2) undeveloped marshland adjacent to industrial areas (large areas south of U.S. Steel and along U.S. Highway 12). A better separation of grassy/agricultural areas from older housing might be expected by collecting data during the summer months, when there is a greater contrast between vegetation and urban classes (9).

Area Calculations

Important tabular data can be generated from machine processing of ERTS data. Table 2 contains an estimate of the proportion of the study area (excluding Lake Michigan) allocated to the various land uses, obtained by a simple tallying of the numbers of data points in each land use class. Adjustments were made for agricultural/grassy areas, commercial/industrial, and older housing, relative to the misclassification between these three land uses (see Table 1). Various land use areas were obtained by multiplying the number of data points by 0.45 for hectares and also 1.1 for acres, the approximate resolution of ERTS. The data in Table 2 could have been reported by small areal units, such as municipalities, townships, or census tracts, by simply storing the desired boundaries in the computer.

TABLE 1. *Classification accuracy for various land uses.*

Land Use	Percentage of Data Points Classified As:					
	C/I ¹	OHg ²	NHg ³	Wod ⁴	A/G ⁵	Wat ⁶
Commercial/Industry -----	89.8	7.3	0.3	--	0.2	2.5
Older Housing -----	0.9	97.9	0.9	0.3	--	--
Newer Housing -----	0.6	4.0	94.0	--	1.4	--
Wooded -----	--	2.0	--	94.4	3.5	--
Agriculture/Grassy -----	0.8	27.4	3.2	3.1	65.5	--
Water -----	0.8	--	--	--	--	99.2

X Classification accuracy by class = 90.3%

¹ Commerce/Industry; ² Older Housing; ³ Newer Housing; ⁴ Wooded; ⁵ Agricultural/Grassy; ⁶ Water.

TABLE 2. *Land use area calculations for study area (excluding Lake Michigan).*

Land Use	No. of Data Pts.	No. of Hectares	No. of Acres	% of Study Area
Commerce/Industry ¹ -----	25766	11479	28343	8.2
Older Housing ¹ -----	56528	25183	62181	18.0
Newer Housing -----	28540	12714	31394	9.1
Wooded -----	52346	23320	57581	16.6
Agriculture/Grassy ¹ -----	150982	67262	166080	48.0
Water -----	499	222	549	0.2
Total -----	314661	140181	346127	100.0

¹ Adjustments made in accordance with test classification accuracy (see Table 1).

Conclusions

Computer processing of ERTS data in the Gary-Hammond area resulted in the mapping of gross land uses with a reasonable degree of accuracy.

Digital, multispectral ERTS data can be readily overlayed and used to monitor land use changes (2). If ERTS data are interfaced with other land use and areal information schemes, planners would have a

computer-compatible land use data bank, with ERTS data as an important, temporal supplement.

Acknowledgements

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Environmental Geology and Land-Use Planning in Boone and Tippecanoe Counties, Indiana

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Abstract

Natural aspects of the land surface (surface drainage, geomorphology, surface and subsurface geology, and distribution of soils) must be considered in proper land-use planning. Boone and Tippecanoe counties lie within the Tipton Till Plain which is influenced by a combination of geologic and pedologic factors and associated engineering characteristics. However, the two counties provided a contrast because of their different rates and extent of urban growth.

Large scale maps are needed to supply the required detail for land-use planning. Maps of the two counties were compiled at 1:24,000 scale ($7\frac{1}{2}'$ quadrangle) depicting the surface geology materials. Engineering interpretations are derived from such maps and used to aid site-selection.

Bedrock-elevation maps were prepared at 1:62,500 scale. Zones with thin glacial cover over bedrock extend across both counties. Tippecanoe County residents experienced problems in such bedrock areas involving septic tank emplacement, foundation excavation and ground water supply. Through proper consideration of the natural aspects, Boone County could benefit from this and other experience gained in Tippecanoe County during its rapid growth period.

Introduction

Natural factors contributing to land surface development must be considered when constructing a good land-use plan for a regional or county-wide area. Included are topography, surface drainage, soil development and surface and subsurface geology. Maps of surface materials and bedrock prepared at a sufficiently large scale to show the necessary detail, plus knowledge of the political-social aspects of a region must be available before a proper land-use plan can be developed.

Boone and Tippecanoe Counties, Indiana, represent an interesting comparison and contrast for land-use studies. Both lie within the same major physiographic province (Tipton Till Plain) and have similar geologic conditions. Tippecanoe County has experienced rapid population growth recently. With the close proximity of Marion County, Boone County likely will soon experience a marked population increase. Similarities in geologic conditions of the two counties provide an opportunity for Boone County planners to learn from the difficulties encountered in Tippecanoe County prior to the establishment of an area planning organization. Such comparison requires discussion of the natural factors in each county which are associated with proper land-use planning.

Methods

Information on surface materials is available for much of Indiana, which is important in land-use planning and space allocation. By presenting such information in map form, the patterns and distribution

of materials are well illustrated, making it easier to relate the importance of various components.

For land-use planning, the mapping should be prepared in sufficient detail to allow an accurate prediction of both beneficial and harmful aspects. In this study, the surface materials were mapped at a scale of 1:24,000 on 7½ minute topographic maps. The surface materials maps were compiled from: 1) agricultural soils maps (4, 9); 2) engineering soils maps (not available for Boone County) (17); 3) air photos; 4) Indiana Geological Survey 1° X 2°, geologic maps (12, 13); and 5) field investigations.

Soils information is of particular importance in regions of thick unconsolidated deposits, particularly in glaciated areas which pertains to the counties studied. McComas *et al.* (5) discussed the usefulness of surface geology and soil units in map preparation.

Bedrock maps were prepared at a scale of approximately 1 inch to 1 mile (1:62,500) from: 1) Indiana Geological Survey maps and reports (10, 11); 2) published ground water reports (2, 7); 3) well-log information on file at the Department of Natural Resources, Division of Water; and 4) files of the Indiana Geological Survey. The maps developed in this study include information concerning the depth to bedrock expressed as unconsolidated material thickness contours, using a 50-foot contour interval.

Results

Tippecanoe County

Tippecanoe County is characterized by flat to gently rolling ground moraine composed primarily of till. This material is the most extensive deposit in the county, although a sizeable portion has been shaped by the Wabash glacial sluiceway, trending northeast across the center of the county. Figure 1 shows the distribution of surface materials in Tippecanoe County. This map is based on published maps (12, 17) and recently completed studies at Purdue University (8, 16). Glacial melt water and the present-day Wabash River have deposited extensive volumes of sand and gravel in the form of terraces, outwash plains, and the river flood plain.

From an engineering standpoint the terrace and outwash deposits of greater Lafayette are excellent for most construction purposes; they contain abundant ground water and exhibit no major foundation problems. Within the past 10 years, however, growth has accelerated and the county population surpassed 100,000, with the major concentration near greater Lafayette. This rapid increase was due partly to the growth of Purdue University in West Lafayette, and partly to development of light and medium industry in Lafayette.

As a consequence of this growth and subsequent urbanization of surrounding areas, limited land-use planning, and lack of consideration for geologic factors, some adverse effects to the community developed.

The wooded, sloping terrain between the low-lying Wabash River floodplain and the upland glacial till plain provides an attractive area

for home sites. Residential development, however, is adversely affected by slope failure and soil creep. The residential area along Happy Hollow ravine in West Lafayette is a good example where slope failure has caused nuisance problems (16). Various methods of slope stabilization have been attempted by homeowners. Not all remedial constructions have been successful, and many through their unsightly design, reduce the beauty of the ravine.

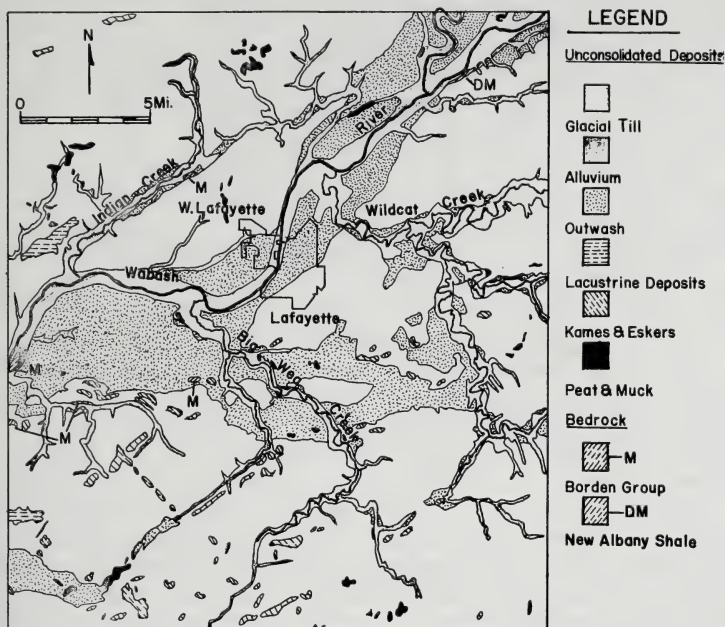


FIGURE 1. Surface materials map of Tippecanoe County, Indiana.

The gravel-rich terrace deposits along the Wabash River are a valuable mineral resource, and are mined in several locations. Immediately south of the Purdue University airport, mining of sand and gravel has left an extensive void in the landscape. Sequential land-use should incorporate reclamation, perhaps for recreational purposes.

An apartment complex, located on the floodplain in West Lafayette, was constructed on hydraulic fill material dredged from the river. Although the building site was elevated about 10 feet in the process, during times of flooding, the basement apartments may be flooded. Construction upon floodplain reduces the cross sectional area of the waterway, thus changing its capacity to carry flood water and encouraging erosion downstream. Care must be taken when constructing on a floodplain to prevent any constriction of floodwater.

Greater Lafayette has three sanitary landfills (two now abandoned) located in permeable deposits adjacent to the Wabash River. Serious problems may develop if landfill leachate migrates with ground water

toward the river or pollutes adjacent sand and gravel aquifers. One abandoned landfill is located south of the Purdue University airport on river terrace deposits in depressions resulting from previous sand and gravel operations. Few homes exist in the area, but the steep ground water gradient toward the Wabash River encourages leachate movement.

A second landfill was located on the north side of Lafayette near the Harrison Street bridge. This landfill, which operated until recently, employed hydraulic fill from the Wabash River to cover the layers of refuse (1). It was located near the river, on the floodplain, and relatively close to the Lafayette municipal water-well field. Leachate from a previous unsupervised open dump has caused the city to abandon one well which became contaminated.

The currently-active landfill site services the greater Lafayette region. It is located north of Lafayette and US 52 By-Pass on the floodplain about 1 mile east of the river. The ground water gradient is sufficiently low that pollution of the river is not an immediate problem, but ground water contamination adjacent to the site is inevitable. Future landfills would function better on the upland till plain in impermeable materials at a safe distance from drainage ways.

Rapid population growth in the Lafayette area has expanded home building into the surrounding countryside beyond the services of city water supply and sanitary sewerage. To illustrate, the Klondike area is located 5 miles northwest of West Lafayette. Here the bedrock rises sufficiently close to the surface to cause serious concern for residential developers (16). The bedrock high trends northeast across Tippecanoe County. The rock unit is a siltstone within the Borden group and is impermeable and non-water bearing. Where this siltstone lies within a few feet of the surface, it is expensive to excavate for full basements. Problems in obtaining ground water occur in adjacent areas where less than 100 feet of glacial drift (mostly till) overlies the siltstone (15). In one subdivision, residents were forced to locate a community well about 1,000 feet away, in unconsolidated materials sufficiently thick to supply ground water. A third associated problem, caused by the impermeability of the rock, involved sewage removal. Septic tank fields do not function where the siltstone lies close to or at the surface and residents were required to install a small sewage treatment facility for waste disposal. These factors have caused inconveniences to the residents resulting in expensive adjustments during and after construction. The engineering problems are illustrated in plan and cross section in Figure 2.

Compressible peat and muck deposits occur sporadically throughout Tippecanoe County and complicate construction of roads and building foundations. Most occurrences have been recognized and adequate precautions taken. Shallow deposits are excavated before construction begins, however, for thicker accumulations, the site is avoided or special construction techniques are employed. Thick peat and muck deposits are a good source of organic material and can be regarded as a natural resource.

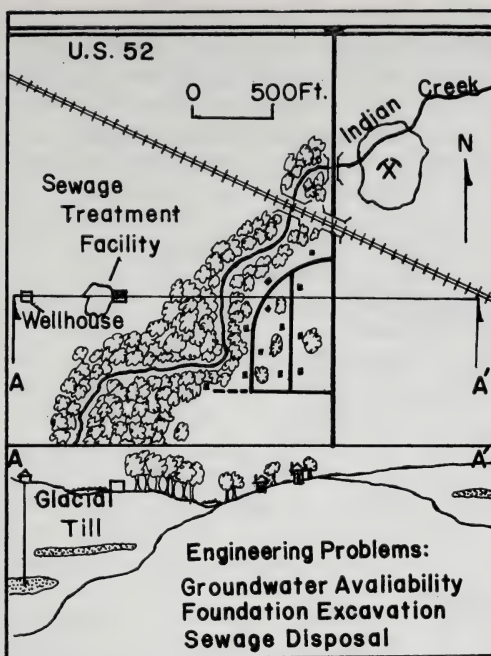


FIGURE 2. Plan and cross sectional view of bedrock high in Klondike area.

Boone County

Boone County, a predominantly agricultural area, is located north-west of Marion County. The current population of about 30,000 represents an increase of only 10,000 people in the past 100 years. During the past 5 years, however, the county has experienced rapid population growth in the Zionsville area resulting from an overflow of people from the Marion County region and an "out to the country" popularity among homebuilders. Two other factors will facilitate population growth: 1) the rapid transportation systems of Interstates 65, 74 and 465; and 2) Old Indiana, a large amusement center proposed for construction along Sugar Creek, northwest of Lebanon. This facility could attract millions of people to the county every year. In view of the possibility of urban expansion at the expense of productive farmland, a land-use plan utilizing geologic considerations for man/earth harmony should be established. Balance between the growing numbers of people and conservation of agricultural resources would thus be provided.

Surface Materials, Landforms and Land-Use Potential. Distribution of surface materials in Boone County is shown in Figure 3. Ground moraine is the most extensive feature present. The maximum thickness is 350 feet, in an area immediately south of Lebanon. These gently rolling, unconsolidated deposits are composed of boulder-clays which are generally poorly drained and have high seasonal perched

water tables. These regions are good for farming and location of sanitary landfills, but present somewhat of a problem for residential development. As this material is impermeable, particularly in the depression areas, septic tank effluent from homes is not readily accepted, and corrections must be made. The ground moraine is a somewhat reliable source of water as thick deposits contain occasional sand and gravel lenses.



FIGURE 3. Surface materials map of Boone County, Indiana. (See Figure 1 for legend.)

Alluvium and floodplain deposits occupy areas associated with the drainageways of Sugar Creek and Eagle Creek. Ideally, these areas should be reserved for agriculture or recreation, but if development prevails, the cross sectional area of the water way should not be reduced. Alluvium provides moderate supplies of water and limited quantities of sand and gravel.

Outwash (valley train) deposits in Boone County are primarily restricted to Sugar Creek and its lower tributaries to the lower segments of Big Racoon and Big Walnut Creeks, and to patches along Eagle Creek. The thickness of sand and gravel is in excess of 100 feet in places. These regions may be a major natural resource for construction materials, and are favorable areas for ground water recharge and withdrawal. They should be outlined and their extent and potential made known to planners. However, outwash is an excellent material for supporting foundations of residential and industrial development. Therefore the quality of the gravel and associated economic factors should be considered along with the ground water potential and possible site development in the determination of the optimum land-use for the area.

Lacustrine plains are regions of flat topography and are composed of stratified silts and clays. One major lake plain occurs in Boone County. It originates in the Lebanon area and "funnels" southwest-

ward. Other patches of lacustrine slack water deposits occur in the western part of the county in association with outwash materials. Agricultural potential is generally promising and residential development may proceed if the land is properly drained.

Thin loess, or wind blown silt, covers the whole county. In the western portion, accumulations in excess of 6 feet are widespread. The distribution is southwest of a northwestward trending moraine. These thick deposits were derived from a local source of outwash and flood plain materials along Sugar Creek. The moraine may have acted as a barrier creating a "wind tunnel" effect thus channeling the deposits to the southeast. Loess provides the best farmland in the county and ideally should be the last areas removed from agricultural production. However, if residential development occurs here, special problems will be encountered. When saturated, loess has a low bearing strength, and structures built on it may settle.

Slope, topography, and other soil forming factors play a role in modifying the glacial drift to produce the well-drained Miami Soil series. The distribution follows a pattern closely associated with the major drainageways and their associated tributaries. These well-drained materials also occupy remnants of the northwestward trending morainal ridge. Numerous kames are included in this group. These areas have a strong potential for residential and some industrial development. Foundation support is good. Septic tanks respond favorably but precautions should be taken because of closeness to surface drainageways.

Bedrock Effects. Bedrock is exposed along Sugar Creek from about 1 mile west of Thorntown to the county line; these outcrops were not previously recognized in the geologic studies of Boone County by Gorby and Lee (3) and Brown (2). This rock is a non-calcareous argillaceous, fine-grained, jointed, thinly-bedded siltstone. It is likely the Carwood formation of the Borden Group (N. M. Smith, pers. comm.), and it presents stratigraphic as well as potential land-use problems. The outcrop occurs too far east for its position in the Borden Group. This area of shallow glacial cover is included within the potential growth region of the county. If development occurs, land-use complications similar to those experienced in the bedrock-associated area in Tippecanoe County may be expected.

Bedrock at depths of less than 100 feet occurs primarily south and west of the buried Knobstone Escarpment which trends northwest through the center of the county. There are a few isolated buried outcrops to the north. Bedrock depths in the eastern part of the county, near Whitestown, are in places less than 25 feet. The probability of obtaining ground water in these shallow (<100 feet) bedrock regions decrease proportionately, particularly when the underlying rock is impermeable.

Conclusions

Work is continuing on environmental geology and land-use studies in both Boone and Tippecanoe Counties. The final objective is to

construct county-wide land-use plans based on the topographic and geologic factors. These plans will depict the beneficial and problematic aspects of an area relative to proposed land-use functions. For those areas in which problems are anticipated, remedial or corrective measures will be suggested, thus providing a positive solution to siting rather than an entirely restrictive approach in which only the "good" sites are acceptable. This additional contribution falls within the traditional area of engineering geology.

The study to date has enumerated several engineering aspects which require consideration in the two counties, as follows:

- 1) Slope stability along actively downcutting streams
- 2) Siting of sanitary landfills
- 3) Septic tank percolation fields
 - a. Impermeable soils
 - b. High, seasonal, perched water tables
- 4) Preservation of natural construction materials (sand and gravel, stone, borrow materials)
- 5) Foundation excavation in bedrock areas
- 6) Compressible, organic soils
- 7) Foundation in loessal and lacustrine deposits
- 8) Ground water supply
- 9) Prevention of ground water pollution
- 10) Storm runoff and local flooding
- 11) Constriction of waterways by construction in flood plains
- 12) Erosion control
- 13) Siltation and sediment transport
- 14) Performance of soils as road subgrades

These 14 items represent a relatively small percentage of the possible geologic hazards that could be compiled on a national scale or to some extent even on a state-wide basis (problems in limestone bedrock areas, for example). The list does focus on the local problems, which is an objective of this study.

A primary purpose of this report was to summarize both existing and new information available on Boone County. Tippecanoe County enjoyed a much greater wealth of compiled geologic information than did Boone County, primarily because Boone County has a smaller population and a lack of obvious, valuable mineral resources.

Compilation of available data is an important beginning for environmental geology land-use applications. Without a careful job here, the succeeding work is rendered inaccurate at best and possibly may be greatly misleading. Geologic information is used to construct the land-use plan. This can be accomplished through the use of overlays (McHarg, 6) and other techniques (Batelle report, 14). For Boone and Tippecanoe Counties, this final work is yet to be performed but the geologic data have been amassed and work is progressing toward development of information for regional land-use planning.

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Environmental Study of Howard County, Indiana: Geologic Aspects

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Abstract

The information necessary to compile a report of this type is available for many Indiana counties. A county soil survey by the Soil Conservation Service and over 600 logs of water wells drilled within Howard County were my data sources.

Maps summarizing the data show the following conditions: 1) the soil in most of the county is not suitable for large housing developments using septic systems; 2) there are numerous areas where wells can be pumped at over 100 gallons per minute; 3) bedrock is usually covered by 50 feet or more of glacial drift; 4) there are numerous areas that are potential sanitary landfill sites; 5) the southwestern portion of the county has a number of sites which are potentially good sources of gravel.

Purpose and Scope

The purpose of this report was to outline the geologic conditions which should be known about Howard County by persons who wish to develop the area.

The most important published reference sources for this study were Deal (2), Nevers and Walker (4), Wayne *et al.* (8), and Burger *et al.* (1). Water well logs from Ortman Drilling, Inc., Kokomo, were also available for this study.

Setting

Howard County is located in north-central Indiana. It comprises 293 square miles and has a population of 83,198 (1970 census). The local relief is one of upland plains and gently rolling hills. It is cut by stream valleys which are seldom more than 30 feet deep.

Bedrock is composed of nearly flat-lying limestones and shales. The bedrock relief (Fig. 4) is about 200 feet. Surface relief bears little relation to the underlying bedrock. The one exception is Wildcat Creek Valley which generally follows a pre-glacial stream valley.

Geologic History

The age of the bedrock ranges from Lower Silurian to Middle Devonian. There are no Lower Devonian rocks and the Middle Devonian Traverse Formation unconformably rests upon the Upper Silurian Salina Formation (1, 8).

A mantle of unconsolidated clay, sand, and gravel was deposited on top of the bedrock by the melting Wisconsin Age glaciers (7). In those areas where there has been little reworking of the sediments by running water there are high percentages of clay. The outwash areas have a lower percentage of clay and a high percentage of sand. In the river valleys the percentage of sand and gravel is very high and the clay fraction very low (2).

Methods of Study

In this study I used 601 water well logs. The information from these logs was transferred to those U.S.G.S. topographic maps which include Howard County. The maps in this paper show the results.

Surficial Deposits

Howard County lies in the Tipton Till Plain (7). This is an area of low relief which the post-glacial streams with their low gradients have not dissected to any great extent.

Deal (2) described the following soil series present in Howard County: Blount, Brookston, Carlisle, Crosby, Fincastle, Fox, Genesee, Hennepin, Kokomo, Linwood, Miami, Morley, Ockley, Patton, Pewamo, and Russell.

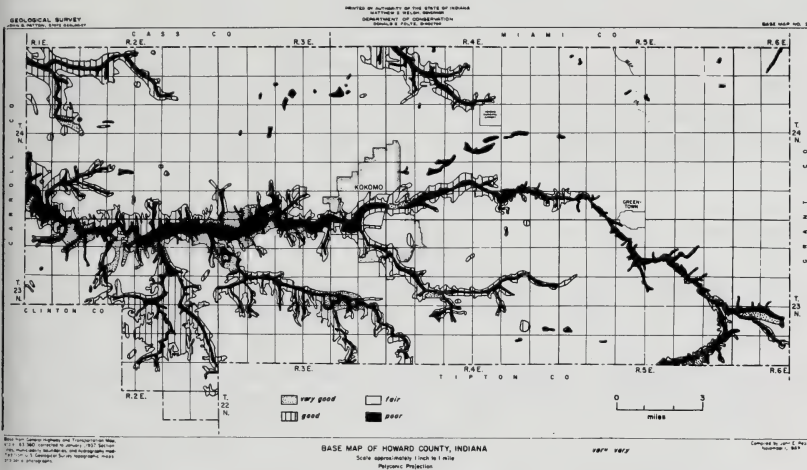


FIGURE 1. *Suitability of soils in Howard County for septic tank filter fields.*

Figure 1 shows the degree of suitability of soils for septic tank filter fields. Very good soils are the Fox and Ockley Series. Good soils are the Miami Series with slopes of less than ten degrees and Russell Series. Fair soils are the Blount, Brookston, Crosby, Fincastle, Kokomo, Morley, Patton (in areas not subjected to floods), and Pewamo Series. These are the bulk of soil types within the county. Poor soils are the Carlisle, Genesee, Hennepin, Linwood, Patton (in areas subject to floods), and Shoals Series.

Ground Water

Water quality is generally satisfactory in the county (3). However, Table 1 shows the sulfates are high in some wells. Figure 2 shows the pressure surface of the ground water. In the county the water table is generally from a few feet to a few tens of feet below ground surface.

TABLE 1. *Raw water quality in Howard County.¹*

	Greentown (1 well)	Kokomo (17 wells avg.)	Kokomo (reservoir)	West Middleton (2 wells avg.)
pH -----	7.7	7.5	8.2	7.7
Color -----	0-5	5	7	5
Turbidity -----	0.7-15	5	25	3-5
Hardness as CaCO ₃ -----	330-350	430	260	340-380
Calcium as Ca -----	77-85	120		85
Magnesium as Mg -----	30-38	30		35
Sodium as Na -----	10	60		15
Potassium as K -----	1-3	2		1
Iron as Fe -----	0.7-1.4	1.9	0.6	0.8-1.0
Manganese as Mn -----	0-0.05	0.2	0.05	0
Alkalinity as CaCO ₃ -----	320-335	320	195	330-360
Chlorides as Cl -----	4-7	13		6
Sulfates as SO ₄ -----	20-25	215		35-45
Nitrates as N -----	<1	0.4		0
Fluorides as F -----	0.6-0.8	0.5		0.5-0.6

¹ Data from Indiana State Board of Health (3). All columns are in parts per million (p.p.m.) except pH, color, and turbidity.

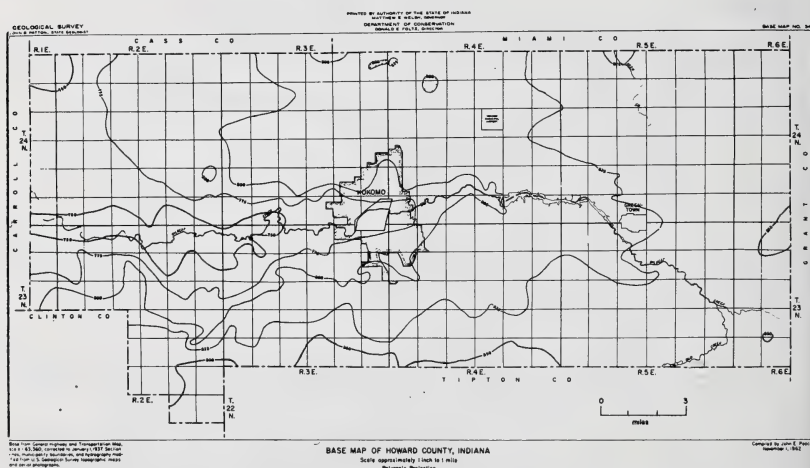


FIGURE 2. *Elevation in feet above sea level of the groundwater pressure surface in Howard County.*

Figure 3 illustrates those areas with wells of flow rates greater than 100 gal/min. The pattern suggests that there are fissure zones within the county which are sufficiently widespread to supply large amounts of water.

The five wells in this study which gave the highest yield in gallons per minute are the following: Midwest Plating and Chemical Co., 950 gal/min (10-inch casing), Kokomo Country Club, 820 gal/min (12-inch casing), Taylor Township School, 650 gal/min (10-inch casing),

Delco Radio Division, 500 gal/min (10-inch casing), and Pittsburgh Plate Glass Co., 425 gal/min (10-inch casing).

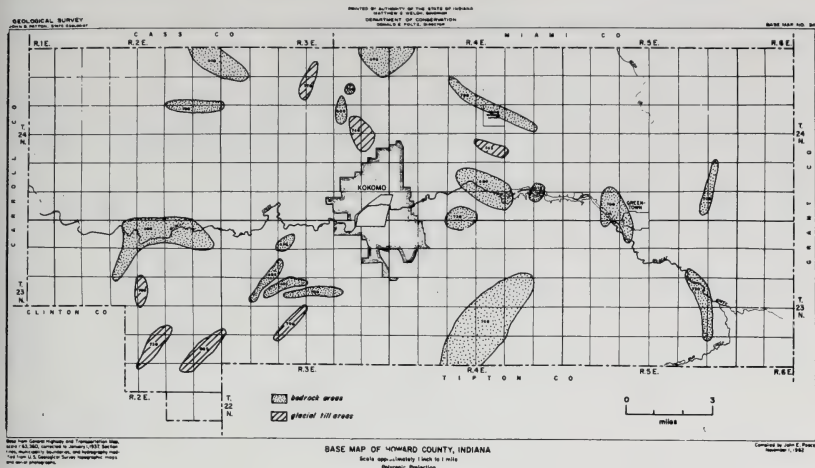


FIGURE 3. Areas in Howard County where flow rates of 100+ gal/min are common. The number within each area is the elevation above sea level at which most of the wells bottom out.

Geology

The bedrock in Howard County is composed of carbonate rocks. The rock formations are described in detail by Shaver *et al.* (5) and Shaver *et al.* (6).

Figure 4 is a map of the bedrock topography. It clearly shows a number of buried sinkholes and pre-glacial river valleys. A comparison

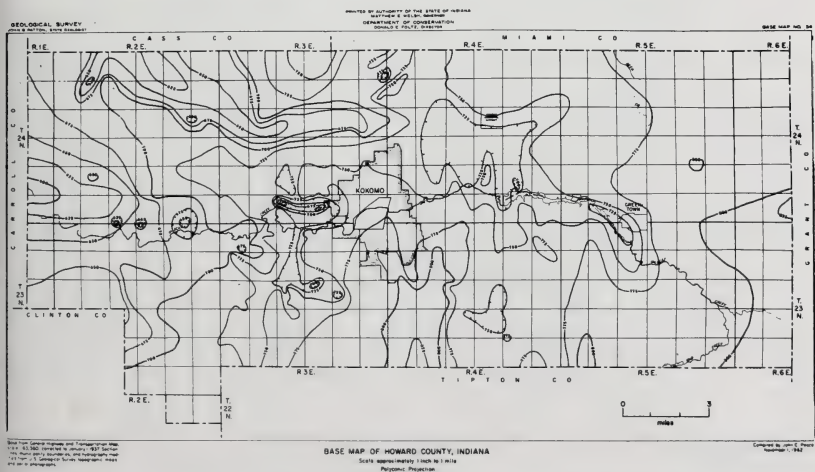


FIGURE 4. Bedrock surface in Howard County. The elevations are in feet above sea level.

of Figure 4 with Figure 3 shows that many high-yield wells are located in bedrock along the sides of pre-glacial river valleys.

Figure 5 shows the drift thickness. The thick drift cover is a detriment to limestone quarrying except along the Wildcat Creek Valley just west of Kokomo.

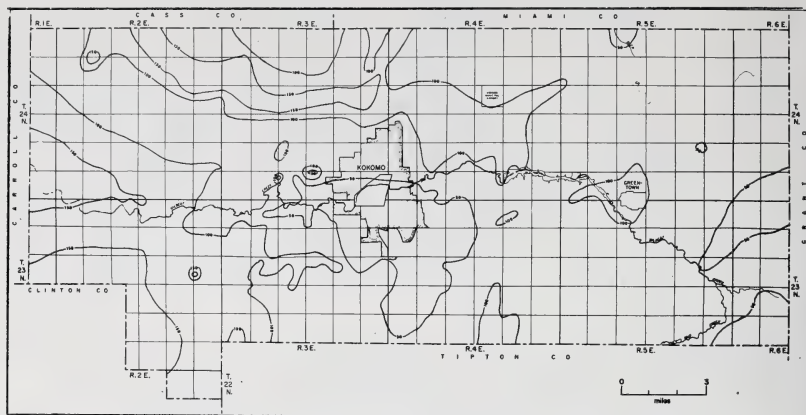


FIGURE 5. Thickness, in feet, of glacial drift covering Howard County.

Figure 6 shows areas which are potentially good sites for sanitary landfills. The most desirable locations are those with a cover of fifty feet or more of clay. Less desirable locations are those with a cover of at least 30 feet of clay. Extensive site studies would be necessary before any of these areas could be approved for such use.

Figure 7 shows areas of gravel deposits which are at least 3 feet thick. The quality of the gravel has not been evaluated in this study.

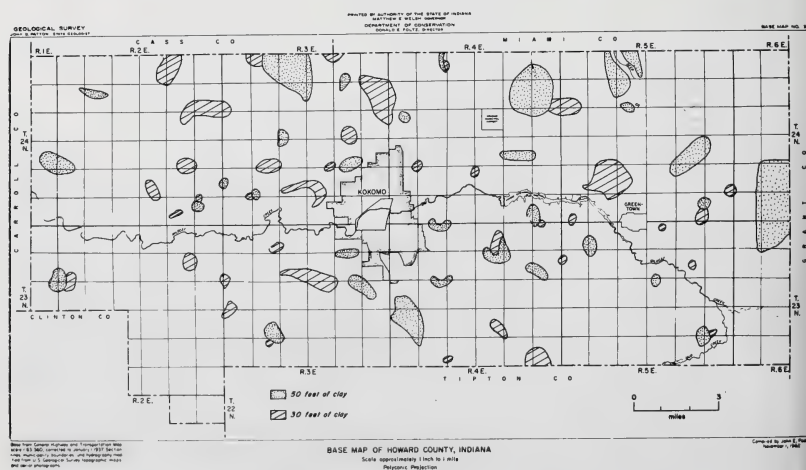


FIGURE 6. Areas in Howard County which are potential sites for sanitary landfills.

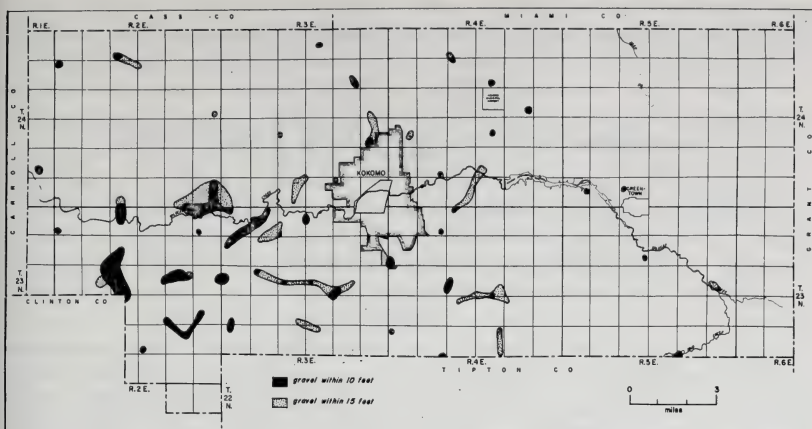


FIGURE 7. Sites of potential gravel deposits in Howard County.

Acknowledgments

I wish to thank Mr. Richard Ortman and Mr. Ned Ortman for allowing me free access to the well logs in their company files.

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Statistical Studies of Indiana Bedrock Velocities: Mapping Applications

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Abstract

More than 11,000 seismic refraction shots were made in Indiana by geophysical crews of the Indiana Geological Survey. Results of these measurements previously were used to measure the thickness of overburden materials. All of the interpreted data are now catalogued on magnetic tape and permit rapid statistical analyses of velocities by computer. Results show that velocities near 1,000 feet per second are associated with dry, aerated or weathered unconsolidated material; those about 6,000 feet per second with water saturated glacial drift or other unconsolidated material; 10,000 feet per second with shales or sandstones; and near 16,000 feet per second with limestone and dolomite. Only slight differences in velocity are noted for rocks having similar lithology but different geologic ages.

Wherever strong velocity contrasts occur between bedrock units, seismic refraction methods offer a technique for subsurface mapping. A portion of Jasper and Pulaski Counties was surveyed by seismic methods. The resulting velocities were plotted on a geologic map and contoured. Contacts between the New Albany Shale and Devonian limestones were well defined by the velocity contours. Lithologic differences within Silurian limestones were also identified.

Introduction

Present knowledge about the geology of the sedimentary section in Indiana was developed over the past century and a half, mainly through studies of surface exposures and investigations of subsurface well records and samples. Unfortunately, this classic geologic approach has faced severe limitations, due primarily to the thick glacial deposits which cover approximately four-fifths of the state, and to the uneven distribution of test wells, both geographically and in depth. Obviously, to form a cohesive regional geologic picture, supplemental information is required for many parts of the state. Ultimately, geophysical methods offer the most convenient and least expensive method for developing the interrelationships and configuration of the sedimentary sequence in all parts of Indiana.

Seismic refraction is the most widely used geophysical technique used in Indiana. Thus far the principal application of these seismic refraction surveys has been to measure the depth to bedrock beneath glacial and alluvial materials. Many of these seismic refraction shots also have been observed to yield limited information about the lithologies of buried bedrock. Results of investigations of these velocity-lithology relationships in Indiana have not been reported previously in geologic literature. These relationships of bedrock velocities with lithologies are vague and difficult to interpret; neverthe-

less, bedrock lithologies deduced from seismic refraction shots may provide the only geologic information for the construction of a complete geologic map. Results of this "refraction velocity-lithology" investigation form an integral aspect of this study.

Although seismic refraction surveys have been used extensively in the exploration for oil in the United States since 1923 (2), little work was done in Indiana by this technique until 1950. At that time a seismic refraction party began a reconnaissance survey to measure the thickness of glacial deposits in northern Indiana for the Indiana Geological Survey. That work later was expanded to include intensive surveys at sites for which foundation information was required, in connection with groundwater investigations, in searches for mineral resources, and to supplement studies of the glacial geology of particular localities. In all, more than 11,000 seismic refraction shots have been made by Geological Survey crews during the past 23 years. Data from these shots are catalogued on computer tapes for rapid access and printout, and have been disseminated widely and incorporated in numerous geologic reports and maps.

The seismic refraction method is based on the physical laws that govern the propagation of light through homogeneous media. These principles are developed in terms of elastic waves in most standard geophysics textbooks (1). Elastic energy propagates outward from an energy source (the shot) as expanding spherical waves, according to Huygen's Principle. Whereas the transmission of elastic energy is derived from Huygen's Principle, the direction of the transmitted or refracted wave is governed by Snell's law:

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2} \quad \text{Equation 1}$$

In this equation the angle of incidence i of a wave (defined with respect to a line drawn normal to the interface between layers) is related to the angle r of the refracted wave directly as the ratio of the interval velocities above and below the interface (V_1/V_2). If the layers are not horizontal, a correction must be applied to the apparent interval velocities in order to obtain the true velocity of the refracted waves. Reverse shots (shots made at each end of the line of recording instruments) record apparent velocities that are greater than true velocities for the up-dip case, and apparent velocities that are less than true velocities for the down-dip direction. True velocity may be obtained from these apparent velocities by a simple mathematical computation.

An accurate interpretation of seismic refraction records depends in part upon geologic conditions at a seismic station. The method is based upon the requirement that velocities of the layers beneath a shot must increase with depth. Where low velocity layers lie beneath layers having higher velocity, refracted energy from the low velocity layers will not be recorded and depths computed for layers beneath the higher velocity material will be erroneous. In some instances for which the velocities

of the layers do increase with depth, refracted energy for a relatively thin intermediate velocity layer may not be recorded by conventional methods. Seismic refraction interpretations, therefore, must be made carefully and in coordination with the best available information about the geology of a locality.

Statistical Summary of Seismic Velocities

Major Stratigraphic Units

A review of 10,745 velocities obtained from seismic refraction shots is plotted in groups of 100 feet/sec (Fig. 1). Where possible, velocities were calculated to include corrections for dipping layers (by reverse shooting), for low velocity layers, and for intermediate velocity layers. Velocities from these shots range from 400 feet/sec to 24,700 feet/sec. Four rather indistinct maxima may be noted on this plot of velocity distribution. One group of velocities is centered about 1,000 feet/sec and represents velocities associated with dry or weathered unconsolidated material. Another group centered about 6,000 feet/sec is characteristic of most unconsolidated material in Indiana. Whether the material is alluvium or Wisconsin glacial deposits appears to have little bearing on the seismic velocity of the deposit. Higher velocities, near 8,000 feet/sec, have been recorded for material that is considered to be Illinoian till. The range of velocities from about 4,000 feet/sec to nearly 9,000 feet/sec is characteristic of saturated or nearly saturated unconsolidated materials that differ mainly in degree of compaction.

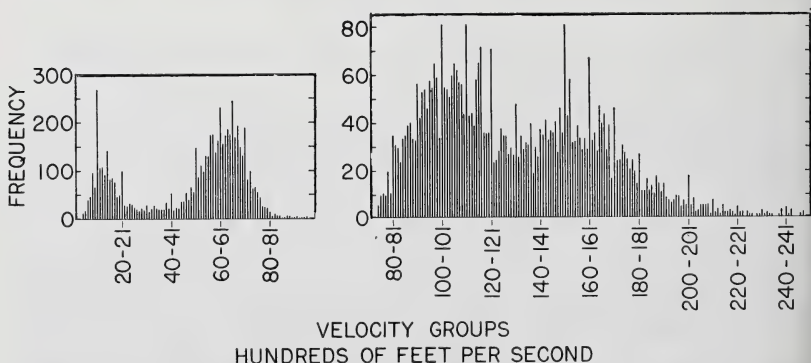


FIGURE 1. Histogram of seismic velocities of Indiana sediments for 10,745 measurements.

In the range of velocities associated with bedrock two indistinct overlapping groups may be observed. The lower of these two has a peak at about 10,000 feet/sec and is characteristic of shales and sandstones. The second group of bedrock velocities, ranging from about 13,000 feet/sec to more than 24,000 feet/sec is related to limestones and is centered about 15,000 feet/sec. Irregular spikes on the plot of velocities (Fig. 1) show some operator bias for certain velocities such

as 1,000, 5,000, 10,000 and 15,000 feet/sec, and a somewhat higher partiality to even than to odd numbers.

In the initial processing of seismic records a geologic age is assigned to bedrock for each station on the basis of the best available information—usually from geologic maps of the area and well data. A lithology is also assigned to bedrock, partly on the basis of geologic maps and well information, and partly on the basis of the bedrock velocity obtained from the time-distance plot for that record. As a result of this interpretation, nearly all velocities have been assigned to two lithologies, shale or limestone. Only 26 shots were interpreted as recording velocities from sandstone.

Statistical analysis of these records, therefore, includes velocities of shales and limestones of five units ranging in age from Ordovician to Pennsylvanian. Table 1 summarizes the results of a statistical analysis of these records. The range and distribution of velocities for Indiana rocks having similar lithologies but quite different geologic ages are almost identical. However, there are measurable differences in velocities of differing lithologies. Shale velocities vary less than those of the limestones. For example, the difference in velocity between the Pennsylvanian shale, having the lowest mean velocity (10,068 feet/sec), and Silurian shales having the highest mean velocity for shales (11,047 feet/sec), is only 979 feet/sec, somewhat less than the lowest standard deviation for shales (1,099 feet/sec). Limestones show a somewhat greater spread in mean velocities—1,793 feet/sec between the Ordovician (lowest) and Devonian (highest). That difference, too, is in about the same range as the standard deviations. The conclusion reached from these comparisons is that shales may be distinguished from limestones, but rocks of the same lithology but different ages cannot be separated on the basis of velocity alone.

TABLE 1. *Average velocities and other statistical data for 8,868 velocities of shales and limestones of Ordovician to Pennsylvanian age.*

Age	Rock Type	Number	Feet per Second	
			Mean Velocity	Standard Deviation
Ordovician	limestone	338	14,538	2,174
Silurian	limestone	1,924	15,195	2,353
Devonian	limestone	1,815	16,331	1,877
Mississippian	limestone	430	15,145	2,143
Pennsylvanian	limestone	42	14,600	1,577
Ordovician	shale	26	10,930	1,365
Silurian	shale	59	11,047	1,099
Devonian	shale	544	10,825	1,195
Mississippian	shale	931	10,269	1,361
Pennsylvanian	shale	2,759	10,068	1,189

Selected Stratigraphic Units

The distributions of velocities shown by the histograms (Figs. 2 to 5) demonstrate several interesting relationships, and pose some

intriguing questions, particularly for cases represented by more than 100 samples. Taken as a group, the limestones show a wide range of velocities, large standard deviations, and because of the large standard deviations, large coefficients of variation and variance (Fig. 2). The range of velocities for the Silurian limestones is exceptionally large, covering 15,500 feet/sec—from 7,000 to 22,500 feet/sec. Distribution of velocities for the limestones is nearly Gaussian, that is skewness is low (0.726 maximum), and kurtosis is close to 3.0. The histogram for the Devonian limestones shows some skewness, which may be explained by the method of record interpretation. For a shot made over the Devonian limestone an arbitrary cutoff was made at a velocity of 12,000 feet/sec at the low end of the scale. All velocities below 12,000 feet/sec were regarded as New Albany Shale. Velocities at the high end of the scale were permitted to go as high as plotted, that is, up to 23,500 feet/sec.

The distribution of shale velocities (Fig. 3) excluding those for Ordovician rocks (26 samples) and for the Silurian rocks (59 samples) is very nearly normal. Standard deviations, coefficients of variation, and variance, generally are lower than those for the limestones. Kurtosis for the distribution of velocities for Devonian and Mississippian shales is below 3.0, that is the curves are slightly flattened; about an equal number of velocities for these shales may be expected in the range from 9,500 feet/sec to 12,000 feet/sec. Skewness is low for the distribution of shale velocities because calculations provided for both high and low arbitrary cutoffs. At the low end, velocities below 8,000 feet/sec were regarded as corresponding to unconsolidated materials; above 14,000 feet/sec the bedrock was considered to be limestone.

A histogram plot of about 4,500 measurements shows a sharp contrast between the average values of 10,400 feet/sec for shales *versus* 15,600 feet/sec for limestones (Fig. 4). However, there is overlap between 8,000 and 15,000 feet/sec because the curve for shale velocities is slightly skewed. Above 12,000 feet/sec, the interpreter tended to regard velocities as typical limestones. However, there is strong contrast and little overlap in the distribution of velocities measured over the stratigraphically adjacent New Albany Shale and limestones of Devonian age (Fig. 5). This relation indicates that velocity may be used to map bedrock geology in areas where contacts are covered by unconsolidated materials; provided the contacts are between rocks of favorable velocity contrast.

Bedrock Lithology Map from Velocities

In a region where bedrock is covered by unconsolidated deposits and where bedrock formations characteristically have contrasting lithologies, a rapid reconnaissance of bedrock geology based on velocities may be made to supplement information from drilling. From a geologic standpoint the Jasper-Pulaski County area offers bedrock having a diversity of ages and lithologic types (Fig. 6). In addition to the now familiar shales and siltstones of the Borden Group, the New Albany Shale, and the Devonian limestones, bedrock also includes the

Michigan Basin equivalents of these rocks. Also present are the Rockford Limestone of Mississippian age and Silurian rocks of the Salina Formation and Niagaran Series.

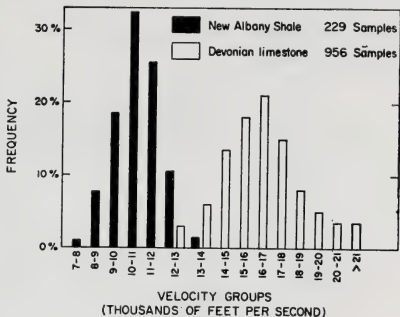
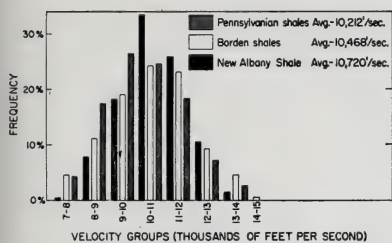
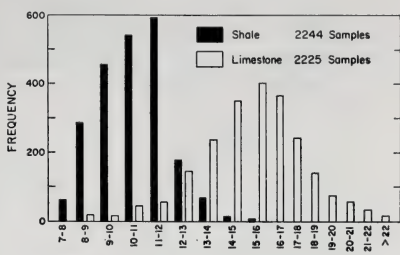
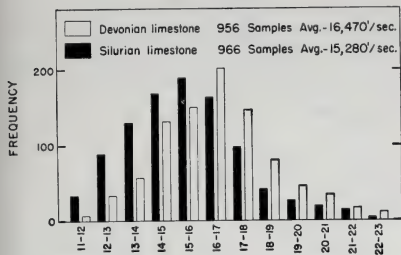


FIGURE 2. Histogram of seismic velocities for some Indiana limestones.

FIGURE 3. Histogram of seismic velocities for some Indiana shales showing differences in three stratigraphic units.

FIGURE 4. Histogram of seismic velocities of Indiana shales and limestones.

FIGURE 5. Histogram of seismic velocities of New Albany Shale and Devonian limestone.

More than 450 seismic refraction shots were made in the Jasper-Pulaski County area to measure the thickness of glacial materials. Where possible, bedrock velocities recorded at each station were corrected for dipping layers, and for errors due to the presence of low and intermediate velocity layers. A map showing bedrock velocity for each seismic station and the most recent interpretation of bedrock geology (Fig. 6) demonstrates the correspondence between velocity and lithology that was indicated by the statistical studies.

Velocity contours on Figure 6 focus attention on certain regional patterns. In the southwestern part of the map there are closely spaced contours that show the separation of New Albany Shale and Devonian limestone. Note that the contours closely parallel the mapped contact. Contours in the north-central part of the map also delineate a similar geologic boundary, although not as closely as the southwestern area. At certain localities underlain by New Albany Shale in the northern part of the area, velocities for that formation were not recorded. This difficulty resulted from the relative thickness and velocities of the glacial drift, New Albany Shale, and underlying Devonian limestone.

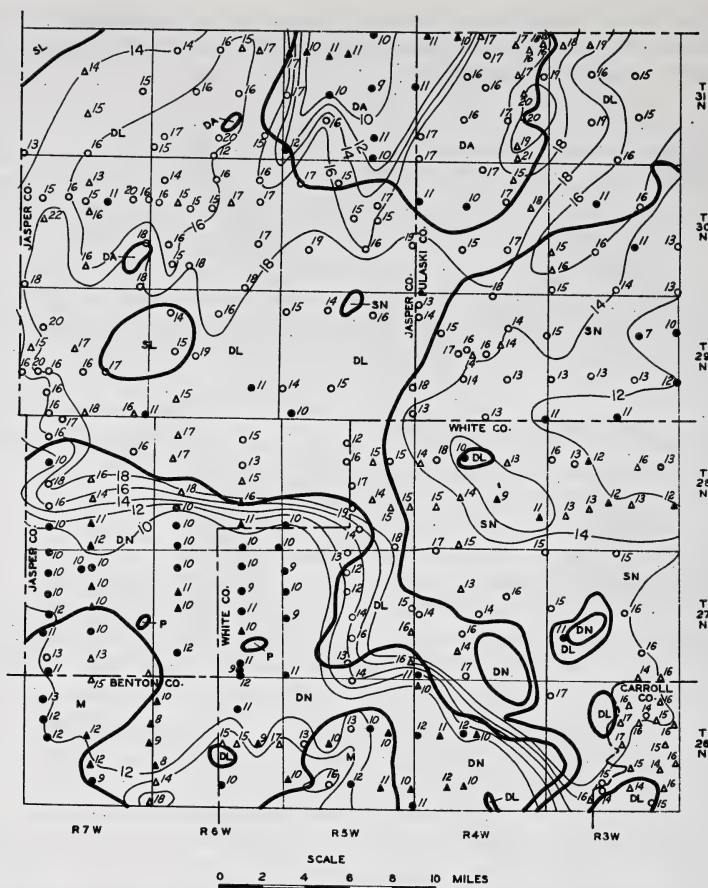


FIGURE 6. Map of a portion of Pulaski and Jasper Counties showing bedrock geology and seismic velocity contours. Heavy solid lines mark geologic contacts between P (Pennsylvanian shale), M (Borden Group and Rockford limestone), DA (Antrim Shale), DL (Devonian limestone), SL (Salina Formation) and SN (Niagaran series). Contour interval is 2000 feet/sec. Solid symbols (circles and triangles) represent measured shale velocities; open symbols represent limestone velocities.

Velocities of Silurian rocks in the eastern part of the map may be used to identify important differences in bedrock lithologies. Regions of 13,000 feet/sec coincide with fine-grained, silty dolomite, whereas velocities in the 15,000-16,000 feet/sec range represent coarsely crystalline, non-silty dolomite. In addition, there are other local areas where the mapped geologic contacts (highly extrapolated) might be altered slightly on the basis of the New Albany Shale-Devonian limestone velocity contrasts. Note that the resolution of velocity data is not sufficient to distinguish between the Borden and New Albany Shales.

Conclusions

Seismic velocities for more than 11,000 refraction shots in Indiana are catalogued on magnetic tape. Data are available on request from the Indiana Geological Survey, Bloomington, Indiana. Extensive statistical studies identify velocities for certain lithologic and stratigraphic units. Applications in mapping buried bedrock geology is feasible with the seismic refraction method in regions of contrasting lithologies.

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Applications of Intensity-Epicentral Distance Relations to Earthquakes Affecting Indiana

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Abstract

Southern Indiana was ranked as having a seismicity only one order less than the highly seismic western region of the United States (1, 10). Indiana has been severely affected by earthquakes located in neighboring states. Sixteen felt shocks had their epicenters in Indiana. The maximum intensity of the strongest shock was VI⁺.

A relationship between intensity and distance was established by isoseismal maps for several azimuths. In general, the fall of intensity with distance is given by the relationship:

$$I_0 - I = N \log_{10} \frac{(\sqrt{X^2 + H^2})}{H} + A \cdot F$$

where I_0 is the maximum intensity, I is the intensity at any epicentral distance, X , H is the depth of focus and N is an empirical term, the value of which depends upon the medium between the focus and the observation point. The last term, $A \cdot F$, expresses the dispersive nature of intensity loss. A is a numerical constant and F is the frequency of a wave. Having the value of N for various azimuths, and given H , A , F and I_0 , I may be computed for any epicentral distance. This technique can be used to determine the effect of predicted earthquakes in a region and to construct probability maps based on past earthquakes.

Seismicity of Indiana and Surrounding States

Sixteen felt earthquakes have occurred in Indiana, ranging in intensity from II to VI⁺. These earthquakes and their intensities are shown in Figure 1. A list of these earthquakes along with other details is given in Appendix 1. Most of these felt earthquakes affecting Indiana are concentrated in the southwest portion. The greatest intensity, VI⁺, occurred in Dubois County near Portersville in 1899. An isolated shock of intensity V was located in Porter County near Porter in 1938 (11).

States bordering Indiana are also seismically active. In fact, more damage has occurred in Indiana due to earthquakes located in the neighboring states than due to earthquakes which occurred within the state. The earthquakes which had maximum intensity in Indiana and its neighboring states are listed below. Their locations are shown in Figure 2:

State	Intensity	Year	Location
Illinois	VII	1909	Robinson
Indiana	VI ⁺	1899	Near Portersville
Kentucky	VI ⁺	1916	Near Hickman
Michigan	VII	1877	Near Dearborn
Missouri	X ⁺	1812	New Madrid
Ohio	VII	1937	Anna
Wisconsin	V	1947	Milwaukee

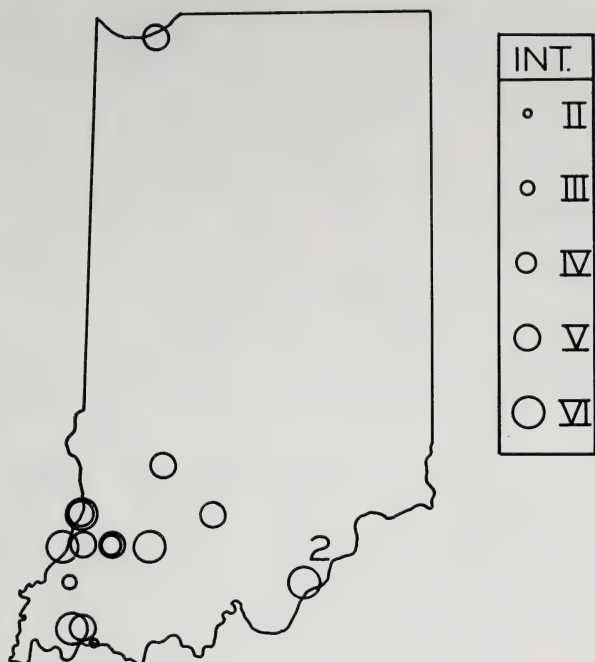


FIGURE 1. Map locating the epicenters of felt earthquakes—Legend shows intensity symbols. (See also the list of earthquakes given in Appendix 1).

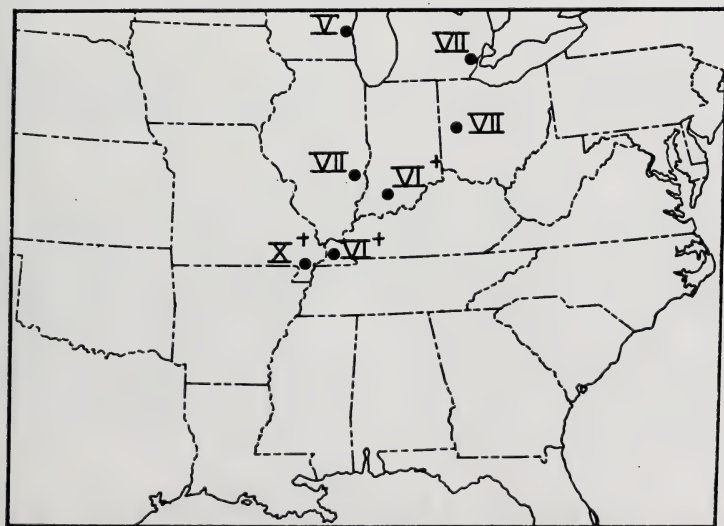


FIGURE 2. Map of southeastern United States showing maximum intensity past earthquakes in Indiana and neighboring states.

Figure 3 is a seismic risk map of the United States (1). It was based on the distribution of damaging earthquakes and their intensities. Consideration was also given to geologic structures. Southern Indiana has been put in Zone 2 which is only one order less in seismic risk than the west coast of the United States which has the highest seismic rating. According to this map we can expect to have an earthquake of intensity VII in southern Indiana which can cause moderate damage to existing structures.

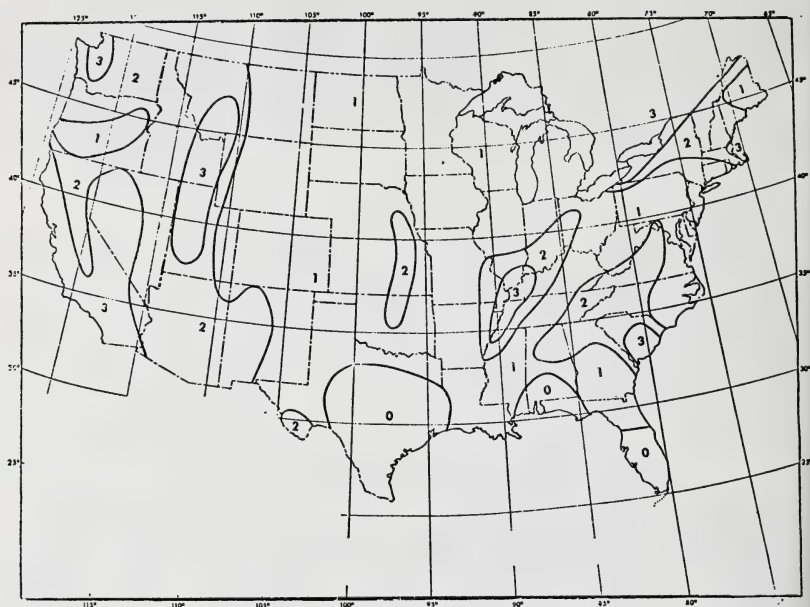


FIGURE 3. *Seismic risk map of the United States; after Algermissen (1).*

Intensity-epicentral Distance Relations

The field investigation of an earthquake results in the preparation of an isoseismal map. Such a map represents areas of equal intensity based on the Modified Mercalli Scale (16) where the earthquake had its effects. As an example Figure 4 is an isoseismal map of an earthquake which occurred in Hamilton County, Illinois, in 1968 (3). From such a carefully prepared isoseismal map, one can obtain very important information regarding the nature of the earthquake and the surrounding geological formation. The decrease of intensity with distance from the epicenter is governed by the following relation (5):

$$I_0 - I = N \log_{10} \frac{(\sqrt{X^2 + H^2})}{H} + A \cdot F \quad [1]$$

I_0 is the intensity at the epicenter, I is the intensity at any epicentral distance X , H is the depth of focus and N is a constant indicative of

the absorptive capacity of the medium between the focus and the observation point. The value of N generally varies between two and six. A is a second absorption term and F is the frequency of a wave. The value of A ranges from 3×10^{-4} to 6×10^{-3} . The $A \cdot F$ term is effective only at very short epicentral distances and is usually ignored in macro-seismic studies.

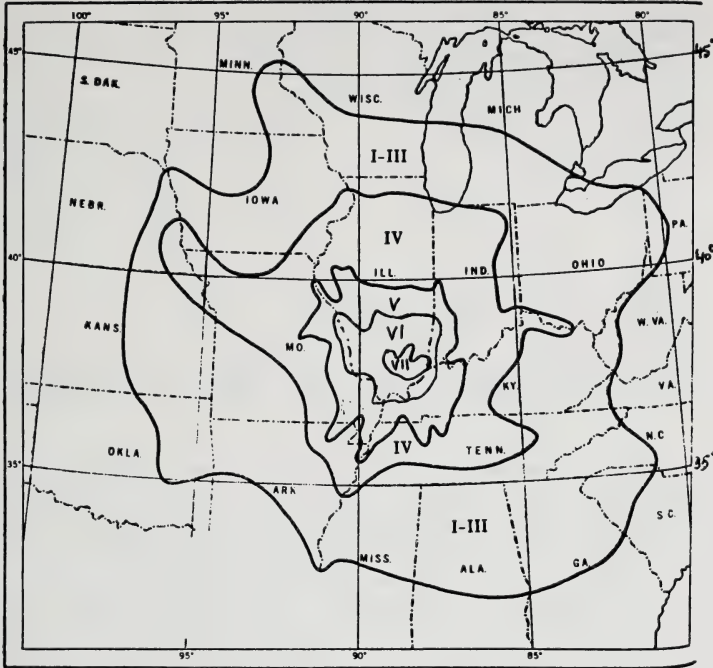


FIGURE 4. Map showing isoseismal areas of Illinois earthquake of November 9, 1968; after Gordon et al. (3).

Using Equation 1, a family of graphs showing drop in intensity with distance was drawn for various values of N and H . One of these (for $N = 3.0$) is shown in Figure 5A. The slopes of the lines are constant after a certain distance. In fact, it is the N value in Equation 1. This can be shown as follows:

When X is much greater than H , Equation 1 reduces to the form:

$$I_0 - I = N \log_{10} \frac{X}{H}$$

OR

$$= N \log_{10} X - N \log_{10} H \quad [2]$$

If $I_0 - I$ is made equivalent to Y , and $\log_{10} X$ equivalent to X (Fig. 5A) then Equation 2 has the form of a linear equation, $Y = NX + \text{constant}$, where N is the slope. The N value indicates the rate of

decrease in intensity with distance for a particular value of depth of focus H . Higher N values yield higher slopes and a rapid decrease of intensity with distance as shown by a comparison of the steeper slopes for $N=5$ (Fig. 5B) with the slopes for $N=3$ (Fig. 5A). Thus N is indicative of the absorption capacity of the medium between the focus and the point of observation.

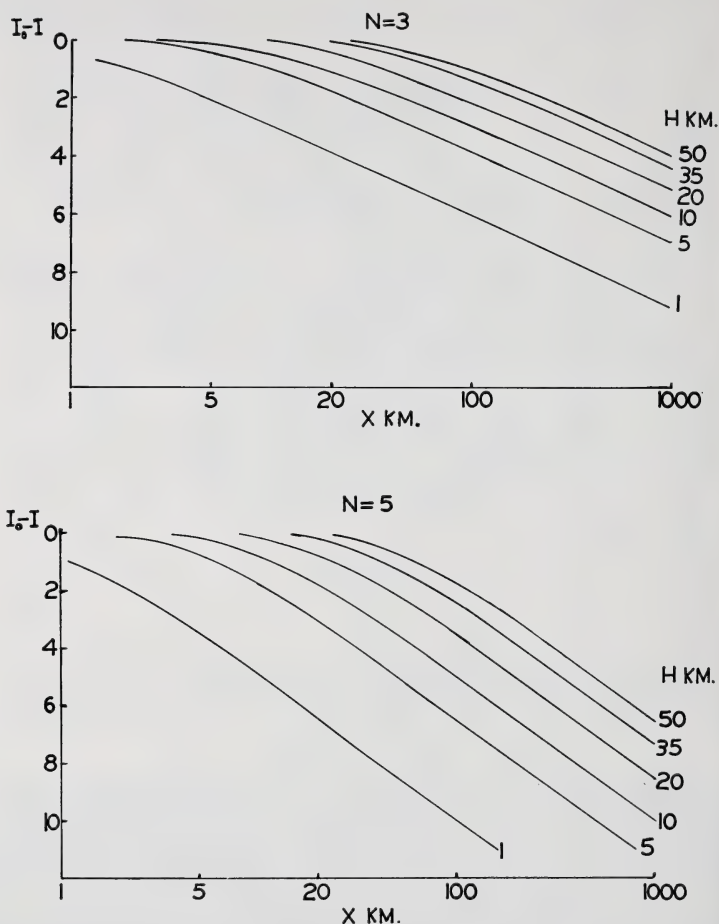


FIGURE 5. Theoretically evaluated decrease of intensity with distance curves for various values of depth of focus H . A. Above—For $N=3.0$; B. Below—For $N=5.0$.

Application of Intensity-epicentral Distance Relations

Such plots may be used to determine the value of N and depth of focus H from an isoseismal map. As an example, the slope of the decrease of intensity with distance curve (Fig. 6) computed from the isoseismal map (Figure 4) of the 1968, southern Illinois earthquake, gives an N value of 3.1. Comparing this curve with the computed

intensity *versus* distance curve for $N=3.0$, the depth of focus is shown to be 31 km, which agrees fairly well with the computed value of 25 ± 5 km from phases read from seismograms.

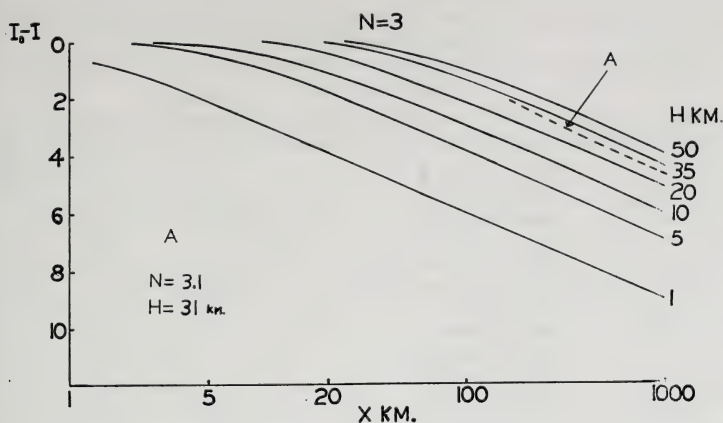


FIGURE 6. Decrease of intensity with distance curve for Hamilton County, Illinois, earthquake of November 9, 1968; (Dashed Line A). By interpolation we find $N=3.1$ and depth of focus $H=31$ km.

N is azimuth dependent because it is indicative of the absorption capacity of the medium between focus and observation point. Data are available in the form of good isoseismal maps for 22 earthquakes in the eastern and central United States for which the value of N has been determined along selected azimuths. The mean value of N and the standard deviation σ , of 2 to 4 determinations for these earthquakes along with other details are given in Table 1. Most of these data are from earthquakes to the southeast, south and southwest of Indiana. Isoseismals for earthquakes located in other regions are being currently constructed from a list of felt earthquakes from all available literature for the eastern and central United States. From a description of each earthquake, a location and intensity have been assigned to it. A list of 715 earthquakes with intensities ranging from II to X+ has been collected for the period 1699-1970.

Future Work

The intensity at any locality may be calculated for any earthquake on the above list from Equation 1 and also the N value for that locality. This technique will be used to make a list of intensities for specific locations. From such a list, ordered by intensity the cumulative probability P_i and return period T_i will be obtained by use of Gumble's (4) statistical method. P_i and T_i is given by the relation

$$P_i = \frac{n_i}{n + 1} \text{ and } T_i = \frac{1}{1 - P_i}$$

where n_1 is the cumulative number of shocks and n is the total number of shocks. Using such a technique, we plan to determine the return period of various intensities for the Indiana area.

TABLE 1. *The 22 earthquakes of eastern and central United States for which the value of N has been determined.*

Date	Location	Maximum Intensity	N	σ
Dec. 16, 1811 -----	New Madrid, MO -----	X ⁻	5.2	0.5
Nov. 2, 1928 -----	Madison Co., NC -----	VI	6.4	2.2
Aug. 29, 1930 -----	Blandville, KY -----	IV	2.7	1.3
April 11, 1934 -----	Arthur City, TX -----	V	3.5	0.5
Jan. 1, 1935 -----	Near Hayesville, NC -----	V	2.9	0.1
April 9, 1952 -----	Near Oklahoma City, OK -----	VII	4.5	1.3
Jan. 25, 1955 -----	Lepanto, AR -----	VI	2.5	0.5
April 9, 1955 -----	Near Sparta, IL -----	VI	3.5	0.6
Jan. 6, 1956 -----	Near Coldwater, KS -----	VI	6.1	0.7
Nov. 25, 1956 -----	Wayne Co., MO -----	VI	2.0	0.2
May 13, 1957 -----	Mitchell Co., NC -----	VI	5.7	2.9
Nov. 24, 1957 -----	NC-TN border -----	VI	9.6	5.3
Aug. 3, 1959 -----	Near Goose Creek, SC -----	VI	3.0	0.6
Oct. 26, 1959 -----	McBee, SC -----	VI	4.3	2.4
Feb. 2, 1962 -----	Near New Madrid, MO -----	VI	2.7	0.9
March 3, 1963 -----	Stoddard Co., MO -----	VI ⁻	5.1	0.6
Oct. 20, 1965 -----	Washington Co., MO -----	VI ⁺	2.3	0.4
June 4, 1967 -----	Near Greenville, MS -----	VI	5.0	0.9
Nov. 9, 1968 -----	Hamilton Co., IL -----	VII ⁻	3.1	0.3
May 2, 1969 -----	Hughes Co., OK -----	V ⁺	3.4	0.1
Nov. 19, 1969 -----	Mercer Co., WV -----	VI ⁻	3.7	0.8
Nov. 16, 1970 -----	Blytheville, AR -----	VI ⁻	6.1	2.4

Conclusions

- 1) Southern Indiana is in a high seismic risk area. The frequency of occurrence of earthquakes in Indiana is low but in the past the state has been severely affected by earthquakes located in the neighboring states.
- 2) Depth of focus H and the N value in the decrease of intensity with distance relationship, $I_0 - I = N \log_{10} \frac{(\sqrt{X^2 + H^2})}{H} + A \cdot F$ can be evaluated from isoseismal maps. The value of N is related to absorption capacity of the medium between the focus of the earthquake and the observation point.
- 3) From the N value, an evaluation of intensity value I can be made.
- 4) Statistical analyses may be used to find the return period and probability of occurrence of an earthquake of any intensity, from the N value and past earthquakes of the region.

Acknowledgement

We wish to thank Professor Judson Mead and Dr. Maurice Biggs for their interest and encouragement during the course of this study.

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APPENDIX 1

List of felt earthquakes having epicenter in Indiana

Sr. No.	Date	Epicentral Region			Intensity	Source of Infor- mation
		Location	Lat. ° N	Long. ° W		
1.	6 Aug. 1827	New Albany	38.3	85.8	VI	(7)
2.	7 Aug. 1827	New Albany	38.3	85.8	VI	(7)
3.	25 Sept. 1876	Near Evansville	38.5	87.6	VI	(2)
4.	6 Feb. 1887	Vincennes	38.7	87.5	VI	(8)
5.	26 July 1891	Evansville	38.0	87.6	VI	(6)
6.	29 Apr. 1899	Near Portersville	38.5	87.0	VI ⁺	(8)
7.	11 May 1906	Petersburg	38.5	87.3	V	(6)
8.	22 Sept. 1909	Near Mitchell	38.7	86.5	V	(2)
9.	27 Sept. 1909	Vincennes	38.7	87.5	V	(9)
10.	25 May 1919	Near Decker	38.5	87.5	V	(9)
11.	26 Apr. 1925	Near Smythe	38.0	87.5	V	(9)
12.	14 Feb. 1929	Near Princeton	38.3	87.6	III	(12)
13.	5 Jan. 1931	Elliston	39.0	86.9	V	(13)
14.	12 Feb. 1938	Near Porter	41.6	87.0	V	(11)
15.	28 Dec. 1940	Near Newburgh	37.9	87.4	II	(14)
16.	9 Aug. 1954	Petersburg	38.5	87.3	IV ⁺	(15)

The Niagaran (Middle Silurian) Macrofauna of Northern Indiana: Review, Appraisal, and Inventory

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Abstract

During the past 130 years more than 360 subgeneric taxa of macrofossils were identified from a few score collection sites in Niagaran (middle Silurian) rocks cropping out in northern Indiana. These fossils served geology well when primary paleontological objectives were to discover and to describe faunas and to use them for stratigraphic correlation. More than this, they came to occupy a niche of special importance in paleontological and stratigraphic literature because they were closely associated with development of the concept of Silurian reefs.

Emphases in paleontological purpose wax and wane, however, and, particularly in the example of the Niagaran fossils of northern Indiana, much recent revision of their assigned stratigraphic order of succession allows this rhetorical question to be asked: what is the residual value of the long but outdated record of Niagaran species in northern Indiana? The record may prove to be even more meaningful than ever before, and to that end this threefold synthesis of updated paleontological data will be a basis for future studies having primary emphases in phylogeny, paleoecology, biozonation, and economic geology:

- 1) A listing of 366 taxa of subgeneric rank intended to include all Niagaran macrofossils previously identified in northern Indiana.
- 2) Identification of all species occurrences in terms of stratigraphic units, distances in feet above or below the base of the Waldron Formation, and paleoenvironments (reef vs. interreef or nonreef).
- 3) Listing of locations of 46 collection sites representing all the recorded species.

Review

Perspective

Cumulative lists of fossil species have been termed a form of pushbroom paleontology. The species of the Niagaran (middle Silurian) macrofauna of northern Indiana are a little like that. The purpose here, nonetheless, is to sweep them a little farther and to suggest the value of this effort. This fauna¹ is one of the classic North American invertebrate faunas. It may number as many as 400 subgeneric taxa, including the synonyms. During the last half of the 19th Century, these Silurian fossils were caught up in the then-grand task of geologists: to decipher the crustal history of the earth, in large part by describing and correlating the sedimentary rocks and their fossil contents on regional, inter-regional, and intercontinental scales. Marine invertebrate fossils constituted the great tool, and still do. Periodically, however, we must see how well the tool has served and, if necessary, refurbish it.

¹ The macrofauna discussed here comes from the formations in northern Indiana that traditionally have been referred to the Niagaran Series (middle Silurian). Thus, the species from the Kokomo and Kenneth Limestone Members of the Salina Formation are excluded even though they could be the same age as some species assigned to the Niagaran Series. Also excluded, therefore, is the Salina fauna referred by Cumings and Shrock (8) to the so-called "Huntington Dolomite" near Logansport that was not then included in the Kokomo and Kenneth lists.

The Basic Studies

The Silurian age of much of the bedrock exposed in the upper basins of the Wabash River and of the West Fork of the White River in northern Indiana was identified by paleontologic means more than 135 years ago by David Dale Owen (17). Subsequently, many geologists compiled special fossil lists during the course of their late 19th Century county and regional reports. The 1898 catalogue of Indiana fossils (12) numbers 72 subgeneric entries for the Silurian of northern Indiana. By 1904, the time of the first comprehensive study of Silurian paleontology in northern Indiana (13), the list had grown to 110 subgeneric taxa, but that number did not include the corals and some other groups of species. A 1915 list (1) republished in 1926 (5) suggests that the number of valid species had shrunk to less than 100, but at the time of the last full coverage in 1928 (8) approximately 275 species and a few subspecies had been indexed.

Since 1928 the known Niagaran macrofauna has been augmented in two principal ways: 1) by a 1930 list (6) for new faunal discoveries made in a reef at Lapel in Madison County and in the collective strata then called the New Corydon Limestone in the area extending from northern Huntington County to Adams and Jay Counties; and 2) by a 1939 list (3) that treated of faunas common to east-central northern Indiana and adjacent Ohio. Neither of these lists had been integrated with the comprehensive 1928 list in terms of a whole faunal perspective.

Concept of Silurian Reefs

The Niagaran macrofauna of northern Indiana has been allied with the development of a major geologic concept, that of fossil reefs. The many outcropping Silurian reefs in the upper Wabash basin also are objects of classic study. Once thought to be evidences of structural upheaval, by Gorby (11), for example, or to have origins like that of Mississippi River mudlumps (13), they are now understood in their true significance. It is partly the fossils in the lists mentioned above that have provided such convincing evidence in the particularly capable hands of Cumings and Shrock (7, 8, 9) that the Silurian faunas and reefs of northern Indiana have assumed a special place in paleontological and stratigraphical literature. Credit must also be given to Phinney (18), however, who in 1891 proposed that organic reefs probably accounted for the previously misidentified moundlike structures in northern Indiana, and before him, to Chamberlin (4), who in 1877 ascribed such origins to similar Silurian rock structures in eastern Wisconsin.

That these earlier fossil studies served a vital need, there can be no doubt, but in later years increasing need to scrutinize the meaning and usefulness of the old faunal lists of Niagaran species has arisen.

Appraisal

Stratigraphic Revision

As one measure of the need, we have learned that the validity of conclusions resulting from the biostratigraphic studies mentioned above

has suffered more than might be expected because of the lack of sub-surface data to be used along with fossil species for the identification and correlation of the Silurian rock units. Many of the species listed in the 1928 compilation (8) as Liston Creek species are in fact Louisville species; some of the listed Huntington species belong to a reeflike, or at least to a bioclastic, high-energy facies in the Salina Formation; the remaining Huntington species for the most part represent reef, reef-flank, and near-reef faunas of the same ages as the more strictly interreef Mississinewa and Liston Creek faunas; and the New Corydon species now are to be assigned to parts of the section ranging from the Salamonie upward to the Liston Creek. (See Figures 1 and 2 herein for the order of Silurian stratigraphic succession in northern Indiana and Pinsak and Shaver (19), Shaver *et al.* (24), and

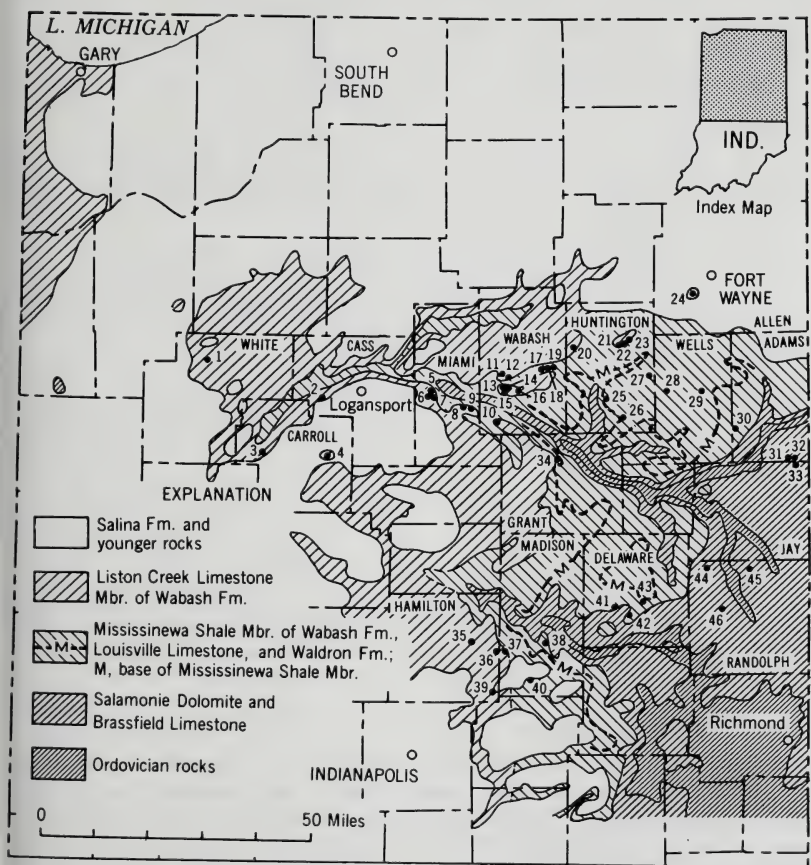


FIGURE 1. Map of northern Indiana showing areal distribution of Niagara (middle Silurian) rock units and fossil-collection sites. The Brassfield Limestone, included with the Salamonie Dolomite in one map unit, belongs to the Alexandrian Series (lower Silurian). See Appendix 2 for exact geographic coordinates of collection sites and Figure 2 for their relative stratigraphic positions.

the Chicago, Danville, Fort Wayne, and Muncie sheets of the Indiana Geological Survey Regional Geologic Map for establishment of present understanding of stratigraphic order.) To whatever extent such problems with stratigraphic identification call into question the validity of the older lists, it seems at least equally clear that new stratigraphic collation is needed to enhance the residual value of the early paleontologic work.

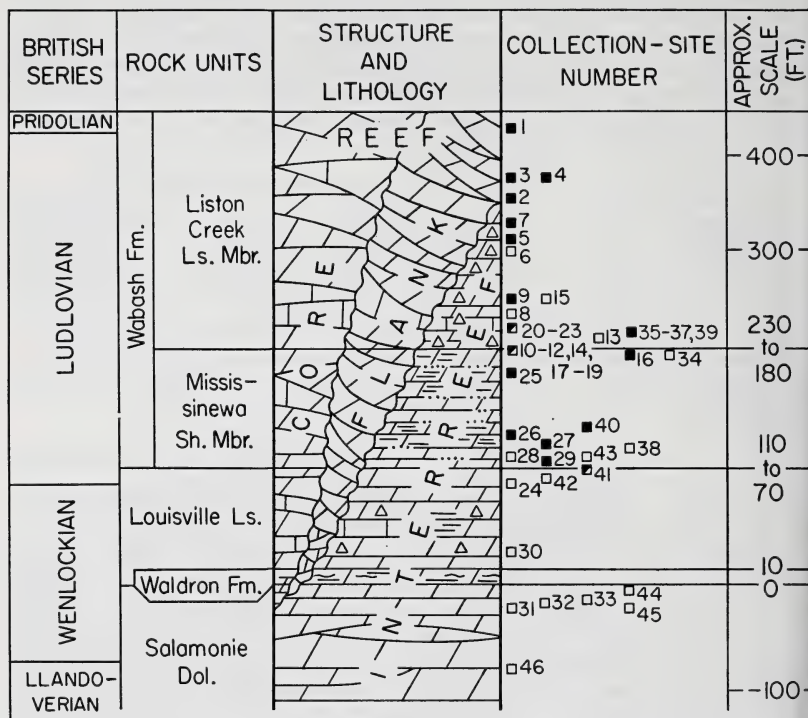


FIGURE 2. Chart showing stratigraphic relationship for collection sites for 366 species of Niagaran (middle Silurian) macrofossils of northern Indiana. See Figure 1 and Appendix 2 for geographic locations of sites. Symbols: solid squares, reef or reef-flank sites; open squares, interreef or nonreef sites; half-closed squares, both kinds of sites.

Paleontological Purpose

The main body of the accumulated list of Niagaran macrofauna (Appendix 1) has seen little addition for several decades. It reached its present proportions during a period when an unstated prevalent theme was that the identification of fossil species and their description was sufficient justification in itself for paleontological study, although such effort, to be sure, was usually made for the purpose of stratigraphic correlation. Further, early paleontological work was conducted with an appreciable amount of comfort provided by the type-specimen method employed in taxonomy. Even though the paleontologist's basic

purpose may have been to correlate, it was easy for him during the period of fossil discovery to assume that his particular collection was a more independent entity than later years have proved it to be.

Expectably, then, present usefulness of paleontological work that is decades old suffers somewhat in proportion to changing methods and emphases. All the early objectives may still be valid, whether identification, description, or correlation, but present objectives in paleontology certainly partake more of phylogenetic and paleoenvironmental considerations. Updating of data on stratigraphic order and facies relationships is a prerequisite.

Refinement of Reef Concept

During the 1940's and 1950's H. A. Lowenstam (14, 15, 16) helped significantly to refine the still-developing concept of Silurian reefs, a concept that has much taken from it to be applied throughout the geologic column, even to the classification of modern reefs. A reef and its organic skeletal structure are partly what they are in contrast to what they are not, and it remained for Lowenstam (14) to put to rest any lingering question of the value of distinction between reef and interreef faunas of Silurian age. Few geologic applications are more dramatic than that made to the traditional geologic belief in the so-called "southern and northern Silurian faunas" and in the two supposedly separate North American seaways and an intervening barrier. Any such remaining paleogeographic concept vanished upon Lowenstam's (14) distinguishing between interreef ("southern") and reef ("northern") faunas. So much of the northern collections from the Great Lakes area proved to consist of reef faunas that sometimes the reef dominance tended to obscure the significance of the lesser parts of northern collections that are at least *nonreef*, if not always strictly *interreef*, in origin. Although distinctions between reef and interreef faunas were made in the earlier period of study, the so-called Huntington fauna, as one example, was thought to come from a distinctly younger formation rather than from the reef to near-reef facies it represents of the basically interreef Mississinewa Shale and Liston Creek Limestone Members of the Wabash Formation (Fig. 2). Thus, even this basic distinction remained until this time to be completed for northern Indiana. A vital part of the Lowenstam concept of Silurian reefs is the interdependence of community (and possibly organic) evolution and the growth of reefs in terms of structure, geometry, composition, and environmental factors. Obviously, no completely valid weighing of this relationship has yet been made in northern Indiana, because so many species (as indicated above) have remained confused in their stratigraphic identities. A study to be published in 1974 (23), however, integrates the Niagaran macrofauna of northern Indiana with modern stratigraphy and the reef concept. The results suggest a major paleogeographic role for the fauna and the reefs in the depositional regimen of the Silurian evaporate-carbonate sequence in the Michigan Basin.

Economic Considerations

A further significance of Silurian reef faunas is economic inasmuch as nearly 100% of reef rock is made up of fossil material, although not at all wholly of taxonomically identifiable entities, and economic exploitation of the reefs presently is increasing, not decreasing.

Much of the crushed stone and other stone-resource industry in northern Indiana and elsewhere in the Great Lakes area is based on Silurian reefs. Reserves, for example, are a function of reef geometry. At the time of writing, buried Silurian reefs formed major reservoirs for oil production in Michigan and formed lesser ones in Illinois and in Indiana. In southwest Indiana the petroleum industry was engaged in a new burst of exploration interest in buried reef structures.

No exaggerated assessment of economic value in modernizing the faunal lists is intended, but it seems obvious that the older paleontological work has become more valuable for pursuing newer kinds of geologic studies than ever its perpetrators thought possible. Whether these studies emphasize environmental reconstruction (*e.g.*, of paleogeographic and physical factors), diagenesis (including dolomitization and development of porosity), or reef geometry and composition, they have potential economic application, and they suggest that interested paleontologists would do well to take their turn with the pushbroom.

Inventory

Revised Macrofaunal List

Some 366 macrofaunal taxa of subgeneric rank have been appraised from the Niagaran rocks of northern Indiana (Appendix 1) in terms of their geographic sources and stratigraphic positions (Figs. 1 and 2, Appendices 1 and 2) and listed in accord by major taxonomic group and facies (nonreef or interreef and reef, including reef flank) (Appendix 1). Three primary literature sources (3, 6, 8) yielded most of the names, but nine other sources, noted as footnotes to Appendix 2, completed the record. The record that is intended to be complete as of early 1973 is the one of fossil names and geographic and stratigraphic positions for each, not at all the list of authors who recorded occurrences. Each source thus yields at least one name or occurrence that would not have appeared otherwise in the list. The list probably has omissions, and interested readers are invited to inform the compiler of omissions.

Some of the sources contain sufficient synthesis of earlier information as to eliminate therein synonyms and invalidly proposed names, as well as to carry forward the more soundly used names. I have not rendered my own taxonomic judgment; that is, I have included what would be synonyms in newer taxonomic work, and have accepted, in effect through this manner of compilation, at least some of the judgment on synonyms that was rendered by earlier workers. Neither have I attempted to use the most up-to-date generic names, my method being to leave the status of these as they were found.

New taxonomic treatment would do much to reduce the species list, by perhaps as much as a third, and the stratigraphic and facies data

supplied here should be vital to taxonomic revision. Of course, taxonomic revision has been going on, but all of it is not reflected in Appendix 1 because of the manner of compilation. A perhaps extreme example is provided by the pentameracean brachiopods (particularly *Conchidium* and *Pentamerus*). A few newer but here unlisted generic names are also presently needed to encompass the 26 species listings, of which probably more than half should be considered as synonyms. Altogether, Appendix 1 hardly suggests by itself the reliable pentameracean zonation in use for Silurian rocks (1, 25).

Repository

Much of the taxonomic evaluation made by Cumings and Shrock (8), partly as a summary of other work, is based on uncatalogued specimens in the Indiana Geological Survey-Indiana University (IGS-IU) paleontological collections. These collections include types for the well-known graptolite fauna described by Shrock (26) and listed in Appendix 1. Also included is a fossil collection (IGS-IU, InGS4-28) from Huntington and Wabash Counties (W. J. Wayne, unpubl. data, 21) (see Appendix 2). Part of Kindle and Breger's (13) types are in the U.S. National Museum (62258-62369). Busch's (3) collection, made partly in east-central Indiana and northward, is housed at The Ohio State University. Altogether, the species listed in Appendix 1 are fairly well documented for Indiana by repositied specimens, but some of the specimens of record were in private collections, and undoubtedly some of the earliest collections were lost or destroyed.

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APPENDIX 1

List of subgeneric taxa of Niagaran (middle Silurian) macrofossils of northern Indiana keyed to stratigraphic and geographic relationships.¹

Receptaculitids

Receptaculites sp., Sa —35 (IR), LC 190 (RE).

Sponges

Astraeospongia n. sp. Lowenstam, LC 235 (IR).

Conulariids

Conularia niagarensis Hall, Sa —20 (IR).

Stromatactids

Stromatactis sp., Mi-LC 203, 208±, 228±, LC 220, 350 (RE).

Stromatoporoids

Clathrodictyon sp., Lo 100 (IR); Mi 85, LC 190, 220 (RE). *C. fastigiatum* Nicholson, LC 185 (IR). *C. ostiolatum* Nicholson, LC 185 (IR). *C. vesiculosum* Nicholson & Murie, Mi 105, LC 185 (IR); Mi (RE). *C. v. minutum* (Rominger), LC 185 (IR). *Stromatopora* sp., Lo 30 (IR); Mi 130, 140, 175, LC 185 (RE). *S. antiqua* (Nicholson & Murie), Sa —20, —35, Lo 75, LC 185 (IR), Lo 76, Mi 85, 130, LC 190 (RE). *S. constellata* Hall, Sa —20 (IR); Mi 85 (RE).

Tabulate corals

Alveolites sp., LC 185 (IR); Mi 130, LC 190 (RE). *A. louisvillensis* Davis, LC 190 (RE). *A. undosus* Miller, LC 185 (IR). *Coenites* sp., Sa —10, —35, Lo 90, LC 185 (IR); LC 190, 192, 220 (RE). *C. aculeata* (Davis), Lo 75 (IR). *C. laqueata* (Rominger), Sa —30, Lo 75, Mi 105, LC 185 (IR); Lo 76 (RE). *C. macrophora* (Hall), Mi 140 (RE). *C. multipora* (Hall), Mi 130, 140, LC 185 (RE). *C. reticulata* (Hall), Sa —30, —35, LC 185 (IR); Lo 76, Mi 85, 130, LC 185 (RE). *C. striata* (Davis), Sa —30, Lo 75 (IR). *Favosites* sp., Sa —10, —35, Mi 105, LC 180 (IR); Mi 85, 130, 140, 175, LC 185, 210±, 220, 350, 370, 375 (RE). *F. favosus* (Goldfuss), Sa —20, —30, —35?; Lo 75, Mi 105, LC 185 (IR); Lo 76, Mi 85, 130, 140, LC 185, 190, 192, 233±, 425 (RE). *F. forbesi* Edwards & Haime, Sa —10, —30, Lo 75 (IR); LC 350 (RE). *F. forbesi occidentalis* Hall, Sa —35 (IR); LC 185 (RE). *F. hisingeri* (Edwards & Haime), Sa —20, —35, LC 185 (IR); Mi 85, 130, LC 185, 190 (RE). *F. hispidus* Rominger, LC 185 (IR); LC 350 (RE). *F. niagarensis* Hall, Sa —10, —20, —25, —30, —35, Lo 75, LC 185, 240± (IR); Lo 76, Mi 85, 130, 140, LC 185, 190, 191, 192, 220, 320, 425 (RE). *F. occidentis* Whitfield, Sa —35 (IR); Mi 85, LC 425 (RE). *Halysites* sp., Mi 85, LC 375 (RE). *H. catenularia* (Linnaeus), Sa —20, —25, —30, —35, —80, Lo 30, 75, Mi 105, LC 185, 233±, 240± (IR); Lo 76, Mi 85, 130, 175, LC 190, 350 (RE). *H. catenularia microporus* (Whitfield), Lo 30 (IR), Mi 85, 130, 175 (RE). *H. labyrinthicus* (Goldfuss), Sa —10, —30, LC 185 (IR); Mi 85; LC 185, 190, 425 (RE). *Romingerella* sp., LC 350 (RE). *Syringopora* sp., LC 185 (IR); Mi 85, LC 192 (RE). *Thecia major* Rominger, Lo 75, LC 185 (IR). *Thecia minor* Rominger, LC 185 (IR); Mi 85, LC 190 (RE).

Nontabulate corals

Amplexus sp., Sa —10 (IR); Mi 85, 130, LC 190, 425 (RE). *A. shumardi* (Edwards & Haime), Sa —80, Lo 75, LC 185 (IR); Mi 85, LC 190, 370 (RE). *Arachnophyllum pentagonum* (Goldfuss), Sa —30, LC 185 (IR); Mi 85 (RE). *A. striatum* (D'Orbigny), Sa —30, Lo 75, LC 185 (IR); Mi 85 (RE). *Blotrophyllum* sp., Sa —35 (IR). *Chonophyllum* sp., Sa —35, LC 185 (IR). *Cyathophyllum* sp., Sa —25 (IR). *C. cf. C. radiculum* Rominger, LC 190 (RE). *Diphyllum caespitosum*, Mi 85 (RE). *Diphyphyllum* sp., LC 185 (IR). *Enteroplasma calicula* (Hall), Mi 205 (IR); LC 191, 192 (RE). *Eridophyllum rugosum* (Edwards & Haime), Mi 105 (IR). *E. sentum* Davis, Mi 85 (RE). *Fletcheria* sp., Mi 85, 130, 140, LC 185 (RE). *F. elegans* (Whiteaves), Mi 85, 130, 140, LC 190, 425 (RE). *F. guelphensis* (Whiteaves), Mi 85, 130, 140, LC 425 (RE). *Favistella* sp., LC 233± (IR). *Heliolites* sp., Lo 30 (IR). *Heliolites elegans* Hall, Lo 76, LC 190 (RE). *H. interstinctus* (Linnaeus), Sa —30, —35, LC 185 (IR); Lo 76, Mi 85, 130, 140, LC 192, 350, 425 (RE). *H. pyriformis* Guettard, Sa —35 (IR). *Lyellia americana* Edwards & Haime, LC 185

(IR); Mi 175 (RE). *Omphyma verrucosa* (Rafinesque & Clifford), Mi 175 (RE). *Plasmopora foliis* Edwards & Haime, LC 185 (RE). *Ptychophyllum* sp., LC 350 (RE). *Syringopora* sp., Mi 85, 175 (RE). *S. retiformis* Billings, Mi 85 (RE). *Zaphrentis* sp., Sa —10, —30, —35, —80, Lo 75, 90 (IR); Lo 76, Mi 85, 130, LC 190, 192, 425 (RE). *Z. celator* Hall, LC 240 (IR). *Z. digoniata* Foerste, Sa —35, Lo 30 (IR); Mi 85 (RE). *Z. racinensis* Whitfield, LC 185 (IR). *Z. stokesi* Edwards & Haime, Sa —20 (IR); Mi 85, LC 190 (RE).

Graptolites

Acanthograptus walkeri (Spencer), Lo-Mi 76 (IR). *Callograptus* sp., Mi 210± (IR). *C. niagarensis* Spencer, Lo-Mi 76 (IR). *C. pullchellus* Shrock, Lo-Mi 76 (IR). *C. p. lazus* Shrock, Lo-Mi 76 (IR). *C. cf. C. striatus* Gurley, Lo-Mi 76 (IR). *Dendrograptus parallelus* Shrock, Lo-Mi 76 (IR). *D. praegracilis* Spencer, Lo-Mi 76 (IR). *D. ramosus* Spencer, Lo-Mi 76 (IR). *Desmograptus cumingsi* Shrock, Lo-Mi 76, Mi 215 (IR). *D. micronematodes* (Spencer), Lo-Mi 76, Mi 130, 200, 215 (IR). *D. m. magnus* Shrock, Lo-Mi 76 (IR). *Dictyonema* sp., Lo-Mi 76, Mi 130, 200, 215 (IR). *D. crassibasale* Gurley, Lo-Mi 76 (IR). *D. filiramus* Gurley, Lo-Mi 76, Mi 130, 200 (IR). *D. lyriforme* Shrock, Lo-Mi 76 (IR). *D. parallelum* Gurley, Mi 130 (IR). *D. percrassum* Gurley, Lo-Mi 76 (IR). *D. polygonum* Gurley, Lo-Mi 76 (IR). *D. polymorphum* Gurley, Lo-Mi 76, Mi 130 (IR). *D. p. virgatum* Shrock, Lo-Mi 76, Mi 130 (IR). *D. tenellum* Spencer, Lo-Mi 76 (IR). *Diplograptus* sp., Mi 215 (IR). *D. (Glyptograptus) niagarensis* Shrock, Lo-Mi 75 (IR). *Inocaulus ramulosus* Spencer, Mi 130, 215 (IR). *Medusaeagraptus mirabilis* Reudemann, Lo-Mi 76 (IR). *Monograptus falciformis* Shrock, Mi 218 (IR). *Thallograptus cervicornis* (Spencer), Lo-Mi 76, Mi 130 (IR). *T. phycoides* (Spencer), Lo-Mi 76 (IR).

Bryozoans

Batostomella granulifera (Hall), LC 240 (IR). *Berenicea consimilis* (Lonsdale), LC 240 (IR). *Chilotrypa ostiolata* (Hall), Mi 210± (IR); LC 310 (RE). *C. varia* (Hall), Mi 205, LC 240 (IR). *Fenestella* sp., Sa —10±, —30, 35±, —80±, Lo 75, LC 223 (IR); Mi 130, LC 185, 190, 192, 310, 350 (RE). *F. cf. F. elegans*, LC 310 (RE). *F. parvulipora* Hall, LC 240 (IR). *F. proluxa* Hall, Mi 205 (IR). *Fistulipora* sp., LC 220 (RE). *F. neglecta maculata* (Hall), Mi 130, LC 192, 220, 240, 310, 320 (RE). *Lichenalia concentrica* Hall, Lo 75, Mi 200, LC 240 (IR). *Monotrypa* sp., Mi 105 (IR). *M. pediculata* Bassler, Mi 205 (IR). *Pachydictya* sp., Sa —30, —35 (IR). *P. bifurcata* (Hall), Mi 85 (RE). *Pinna-topora* sp., LC 310 (RE). *Polyppora* sp., LC 310 (RE). *P. cf. P. punctostriata* (Hall), LC 310 (RE). *Pseudohornera niagarensis* (Hall), LC 310 (RE). *Demicosinium acumcum* (Hall), Mi 205 (IR). *S. cf. S. acmum* (Hall), LC 310 (RE). *Spatiopora maculata* (Hall), LC 240 (IR). *Stictotrypa? punctipora* (Hall), Mi 205 (IR). *Striatopora? flexuosa* Hall, Mi 205 (IR).

Articulate brachiopods

Anatrophia internascens Hall, Sa —35, LC 300 (IR); Mi 85, 115, LC 220, 310 (RE). *Atrypa calvini* Nettleroth, Mi 115, 130, 175, LC 190, 191, 192, 350 (RE). *A. reticularis* (Hall), Sa —10, —20, —25, —35, —80, Lo 75, Mi 205, 210±, LC 225, 240±, 300 (IR); Mi 85, 130, LC 185, 190, 191, 192, 220, 310, 350, 370 ☒ (RE). *Bilobites bilobus* (Linnaeus), Mi 205, LC 240± (IR). *Camarotoechia* sp., Sa —25, LC 300 (IR); Mi 115, LC 185, 190, 370 (RE). *C. acinus* (Hall), Sa —10, —35, Lo 75, LC 300 (IR); LC 350 (RE). *C. indianaensis* (Hall), Sa —35, LC 300 (IR); LC 310 (RE). *C. (Stegorhynchus) neglecta* (Hall), Sa —35 (IR); LC 185, 220, 310 (RE). *C. (S.) whitei* (Hall), LC 310 (RE). *Chonetes* sp., Sa —35 (IR); Mi 115 (RE). *Clorinda ventricosa* (Hall), Sa —35 (IR); Mi 130 (RE). *Conchidium* sp., Lo 75, 100 (IR); Mi 130, LC 185, 192, 350, 370, 375, 425 (RE). *C. biloculare* Linnaeus, Mi 85 (RE). *C. cf. C. biloculare* Linnaeus, LC 425 (RE). *C. greeni* Hall & Clarke, LC 185 (RE). *C. knighti* Nettleroth, Mi 85 (RE). *C. lagueatum* (Conrad), Sa —30, —35, Lo 30 (IR); Mi 85, 130, LC 185, 190, 192, 350, 375, 425 (RE). *C. littoni* (Hall), Mi 85, 130, LC 190 (RE). *C. cf. C. littoni* (Hall), Mi 140, LC 185, 192, 350 (RE). *C. multicostratum* (Hall), Lo 100, LC 185 (IR); Mi 85, 130, LC 185, 190; 191, 192, 425 (RE). *C. nettlerothi* Hall & Clarke, Mi 85 (RE). *C. n. sp.* Busch, Mi 85 (RE). *C. nysius* Hall & Whitfield, Mi 130, LC 190 (RE). *C. occidentale* Hall, Mi 85 (RE). *C. tenuicostatum* (Hall & Whitfield), Mi 85 (RE). *C. trilobatum* Kindle & Breger, Mi 85, LC 185 (RE). *C. unguiformis* Ulrich, LC 370 (RE). *Cyrtia exporrecta* (Wahlenberg), Mi 210±

(IR); LC 375 (RE). *C. exporrecta myrtia* (Billings), Lo 75 (IR); LC 190, 350, 375 (RE). *Dalmanella elegantula* (Dalman), Sa —35, Lo 30, 75, Mi 210±, LC 300 (IR); Mi 140, LC 170, 190, 191, 192, 220, 350, 370 (RE). *Gypsidula* (*Sieberella*) *galeata* (Dalman), LC 191, 220, 320, 350, 370 (RE). *G. (S.) nucleus* (Hall & Whitfield), Mi 115, LC 350 (RE). *Leptaena rhomboidalis* (Wilckens), Sa —10, —25, —30, —35, —80, Lo 75, Mi 215, LC 225, 240 (IR); Mi 115, 140, LC 190, 191, 192, 220, 310, 350 (RE). *Meristina* sp., Mi 140 (RE). *M. maria* (Hall), Sa —10, —30, —35, Lo 30, LC 185 (IR); Mi 115, LC 190, 191, 220, 240±, 350 (RE). *M. cf. M. princeps* (Hall), LC 350 (RE). *M. rectirostris* Hall, LC 220, 370 (RE). *Nucleospira pisiformis* Hall, LC 300 (IR); Mi 115, 140, LC 191, 192, 220 (RE). *Orthis benedicti* Miller, LC 240 (IR). *O. flabellites* Foerste, Mi 115, LC 190, 220, 320, 370 (RE). *O. subnodosa*, LC 370 (RE). *Pentamerus* sp., LC 190 (RE). *P. n. sp.* Cumings, LC 310 (RE). *P. oblongus* Sowerby, Sa —10, —20, —25, —30, —35, —80, Lo 30, 75, 90 (IR); Lo 76, Mi 130, 140, LC 185 (RE). *P. o. compressus* Kindle & Breger, LC 375 (RE). *P. o. cylindricus* (Hall & Whitfield), Sa —35, Lo 75 (IR); LC 375 (RE). *P. ovalis* Hall, Lo 30 (IR). *P. pergibbosus* Hall & Whitfield, Sa —35, Lo 30 (IR); Mi 140 (RE). *Pholidostropia niagarensis* Kindle & Breger, LC 370 (RE). *Plectambonites* cf. *P. siriceus* (Sowerby), LC 192 (RE). *Rhipidomella circulus* Hall, LC 350 (RE). *R. hybrida* (Sowerby), Sa —10±, —30, —35±, —80±, Lo 75, Mi 205, LC 300 (IR); Mi 115, 130, LC 192, 240, 310, 370, 375, 425 (RE). *Rhynchotrete cuneata* (Hall), LC 240±, 350 (RE). *Schizophoria* sp., Lo 30 (IR). *Schizotrete tenuilamellata* (Hall), Lo 75 (IR). *Schuchertella* sp., Sa —35 (IR); *S. subplana* (Conrad), Sa —10, LC 223 (IR); Lo 76, Mi 115, LC 190, 191, 220, 310, 350, 375 (RE). *S. radiatus*, Lo 75, 90, Mi 200 (IR); LC 220 (RE). *S. tenuis* (Hall), LC 220 (RE). *Spirifer* (*Delthyris*) *crispus* (Hisinger), LC 240, 300 (IR); Mi 140, LC 190, 191, 192, 310, 350 (RE). *S. (D.) c. simplex* (Hall), Sa —10, LC 300 (IR); Mi 115, LC 192, 310, 350, 370 (RE). *S. (Eospirifer) eudora* (Hall), Sa —10, —30 (IR); LC 320, 350 (RE). *S. (E.) nobilis* (Barrande), Mi 115, LC 190, 191, 192, 350 (RE). *S. (E.) radiatus* (Sowerby), Sa —10, —35, —80, LC 185 (IR); Mi 85, 115, LC 185, 191, 192, 320, 350, 370, 375 (RE). *S. cf. S. radiatus* (Sowerby), LC 191 (RE). *S. foggi* Nettleroth, LC 190, 192, 350 (RE). *Stropheodonta* sp., LC 191, 310 (RE). *S. (Brachyprion) profunda* Hall, Sa —10, —20, —30, —35, Lo 30, 90 (IR). *S. cf. S. corrugata* (Conrad), LC 350 (RE). *Stricklandinia* sp., LC 190 (RE). *S. gaspiensis* (Billings), Mi 85, LC 192 (RE). *Strophonella* sp., LC 192, 320 (RE). *S. semifasciata* (Hall), Lo 30 (IR); LC 190, 310 (RE). *S. striata* (Hall), Sa —10, —35, Lo 75, Mi 200, 205 (IR); Mi 140, LC 190, 191, 192, 220, 310, 320, 350 (RE). *S. williamsi* Kindle & Breger, Mi 115, LC 192, 350, 375 (RE). *Trematospira* sp., LC 310 (RE). *Trematospira* cf. *T. camura* (Hall), LC 310 (RE). *Uncinulus stricklandi* (Sowerby), Sa —35, Lo 90 (IR). *Whitfieldella* sp., Sa —25, —30 (IR); Mi 130 (RE). *W. cf. W. marylandica* Prouty, LC 190 (RE). *W. nitida* (Hall), Sa —10, —35, Lo 90, Mi 215, LC 185, 240 (IR); LC 190, 310, 350, 370, 425 (RE). *W. n. oblata* (Hall), Sa —35 (IR). *Wilsonia saffordi* Hall, LC 350 (RE). *Wilsonia* cf. *W. saffordi*, LC 310 (RE).

Inarticulate brachiopods

Crania sp., Mi 115 (RE). *Dinobolus conradi* (Hall), LC 185 (RE). *Monomorella* sp., LC 375 (RE). *M. noveboracum* Clarke & Reudemann, LC 185 (RE). *Trimerella* sp., LC 375 (RE).

Pelecypods

Ambonychia sp., Mi 215 (IR). *Amphicoelia leidyi* Hall, Sa —35 (IR); LC 350 (RE). *A. neglecta* (McChesney), LC 220 (RE). *Anodontopsis wabashensis* Kindle & Breger, LC 220 (RE). *Clidophorus consuitus* Ulrich, Sa —35 (IR). *Conocardium multistriatum* Kindle & Breger, LC 350 (RE). *C. oweni* Kindle & Breger, LC 192, 370 (RE). *Cypricardinia* sp., Mi 115 (RE). *C. undulostriata* (Hall), Sa —10 (IR). *C. cf. C. undulostriata* (Hall), LC 300 (IR). *Leiopetelia subplana* (Hall), LC 310 (RE). *Megalomus canadensis* Hall, LC 425 (RE). *Mytilarca* sp., Sa —35 (IR). *M. acutirostra* (Hall), LC 240 (IR). *M. sigilla* Hall, Sa —35 (IR). *Paleopinna* sp., LC 220 (RE). *Plethomytilus cuneatus* Kindle & Breger, Sa —35 (IR); LC 350 (RE). *Pterinea* sp., Sa —20, —35 (IR); LC 375 (RE). *P. emacerata* (Conrad), LC 310 (RE). *Streptomytilus wabashensis* Kindle & Breger, Mi 210± (IR); LC 220 (RE).

Gastropods

Bellerophon shelbiensis Clarke & Reudemann, Mi 85, LC 350, 425 (RE). *Bucania* sp., LC 350 (RE). *Coelocaulus* sp., LC 185 (RE). *C. bivittatus* (Hall), LC 185 (IR); LC 185 (RE). *C. macrospira* (Hall), Sa —35 (IR). *Cyclonema cancellata* Hall, LC 350, 370 (RE). *Diaphorostoma* sp., Mi 115 (RE). *D. niagarensis* (Hall), Sa —35, Lo 75, Mi 210±, LC 225 (IR); LC 192, 220, 350, 370, 425 (RE). *Eotomaria* sp., Mi 200, 215 (IR). *E. gallensis* (Billings), Mi 85, 130 (RE). *E. laphami* (Whitfield), Mi 210± (IR); LC 375 (RE). *Euomphalopterus alatus limatoideus* Kindle & Breger, LC 350, 370, 375 (RE). *Hormotoma* sp., Mi 210±, 215 (IR); LC 425 (RE). *Liospira perlata* (Hall), LC 185 (RE). *Lophospira* sp., LC 185, 425 (RE). *Loxonema? leda* Hall, Mi 210± (IR). *Platyceras* sp., LC 192 (RE). *P. niagarensis* (Hall), Sa —80 (IR); Mi 85 (RE). *Pleurotomaria* sp., Sa —20 (IR); LC 375 (RE). *P. axion* Hall, LC 185 (RE). *P. eloroidea* Kindle & Breger, Mi 85, 130, 175, LC 185, 375 (RE). *P. hoyi* Hall, LC 375 (RE). *P.? idia* Hall, Mi 85, LC 185 (RE). *Poleumita* sp., Sa —30, LC 185 (IR); LC 190, 350, 375, 425 (RE). *P. crenulata* (Whiteaves), Mi 130 (RE). *P. huntingtonensis* (Kindle & Breger), Sa —10 (IR); LC 185 (RE). *P. h. alternata* (Kindle & Breger), LC 185 (RE). *P. opercula* (Kindle & Breger), Mi 130 (RE). *P. plana* (Kindle & Breger), LC 350 (RE). *P. scamnata* Clarke & Reudemann, Sa —30, —35 (IR); Mi 130, 175 (RE). *Schizolopha* sp., LC 375 (RE). *Straparollus* sp., Mi 215 (IR). *S. mopsus* Hall, Mi 85, 140 (RE). *S. niagarensis* Hall & Whitfield, Mi 85 (RE). *Strophostylus cancellatus*, Sa —35 (IR); Mi 175 (RE). *S. cyclostomus?* (Hall), Mi 130 (RE). *S. elevatus* Hall, LC 185 (RE). *Subulites terebriformis* (Hall), Sa —35 (IR). *Tremanotus alpheus* (Hall), Sa —35, Lo 30 (IR); Mi 85 (RE). *T. chicagoensis* McChesney, Lo 30 (IR); Mi 85, 130, LC 185, 375 (RE). *Trochonema pauper* (Hall), LC 185 (RE). *Turritoma laphami* (Hall), Sa —35 (IR); LC 185, 375 (RE).

Cephalopods

Actinoceras sp., LC 190 (RE). *Ascoceras newberryi* Billings, LC 375 (RE). *A. wabashense* Newell, LC 375 (RE). *Bickmorites bickmoreanus* (Whitfield), Sa —35, LC 210±, 240 (IR); LC 185, 350 (RE). *Cycloceras amycus* (Hall), Lo 30 (IR). *Cyclostomiceras orodes*, Sa —35 (IR). *Cyrtoceras gorbyi* Kindle & Breger, LC 185 (RE). *Cyrtorizoceras dardanum* (Hall), Mi 205 (IR). *Dawsonoceras americanum* (Foord), LC 310 (RE). *D. annulatum* (Sowerby), Sa —30, —35, Lo 30, 75, LC 185 (IR); Mi 85, LC 185, 310, 375 (RE). *Discoceras* n. sp. Phinney, Mi 205 (IR). *D. graftonense* (Meek & Worthen), LC 240 (IR). *D. marshi* (Hall), LC 223, 240 (IR); Mi 85, LC 425 (RE). *D. cf. D. marshi* (Hall), LC 310 (RE). *Gomphoceras lineare* Newell, LC 240 (IR). *G. projectum* Newell, LC 375 (RE). *G. scrinium* Hall, LC 350 (RE). *S. subgracile* Billings, Mi 205 (IR). *G. wabashense* Newell, LC 223, 240 (IR); Mi 85, LC 375 (RE). *Hexameroceras* sp., Mi 175 (RE). *H. cacabiforme* Newell, LC 240 (IR); LC 375, 425 (RE). *H. delphicum* Newell, LC 185, 375 (RE). *H. hertzeri* (Hall & Whitfield), Mi 85, LC 185 (RE). *Kionoceras* sp., LC 190 (RE). *K. cancellatum* (Hall), Lo 75, Mi 200, LC 240 (IR); Mi 85, LC 185, 190, 192, 310, 370, 375, 425 (RE). *K. darwini* Billings, Mi 140, 170 (RE). *K. delphiense* Kindle & Breger, LC 375 (RE). *K. strix* (Hall & Whitfield), Mi 205, LC 240 (IR). *Lechritochoceras desplainense* (McChesney), Mi 85 (RE). *Mandaloceras scrinium* (Hall), Mi 85 (RE). *M. subgracile* (Billings), Mi 85 (RE). *Orthoceras* sp., Sa —10, —20, —30, —35, Lo 30, 75, 90 (IR); LC 350, 425 (RE). *O. alienum* Hall, LC 233± (IR). *O. obstructum* Newell, LC 240 (IR). *O. rigidum* Hall, LC 240 (IR). *O. simulator* Hall, Sa —30, —35, Lo 30, 75 (IR); Mi 85 (RE). *O. unionense* Worthen, LC 240 (IR). *Pentameroceras cumingsi* Flower [= *P. mirium* (Barrande)], LC 250, 375 (RE). *Phragmoceras* sp., Lo 75 (IR); LC 425 (RE). *P. angustum* (Newell), LC 240 (IR); Lo 76 (RE). *P. ellipticum* Hall & Whitfield, Mi 205 (IR); Mi 85, LC 185 (RE). *P. nestor* Hall, Mi 205, LC 240 (IR); LC 425 (RE). *P. parvum* Hall & Whitfield, Sa —35, LC 240 (IR); LC 185 (RE). *Protokionoceras* sp., Lo 75 (IR). *P. crebescens* (Hall), Mi 205, LC 225, 240 (IR); Lo 76, Mi 85 (RE). *P. medullare* (Hall), Lo 75, Mi 120, 210± (IR); LC 185, 375 (RE). *P. trisutum* (Clarke & Reudemann), Mi 210± (IR); Mi 85, 130 (RE). *Protophragmoceras hercules carollensis* Kindle & Breger, LC 375 (RE). *Spyroceras* sp., Mi 215 (IR). *Trimoceras gilberti* Kindle & Breger, LC 223 (IR); LC 185, 375 (RE). *Trochoceras* sp., Sa —20 (IR). *T. cf. T. costatum* Hall, Mi 210± (IR). *T. desplainense* McChesney, LC 240 (IR). *T. cf. T. desplainense* McChesney, LC 185 (RE). *Trocholites* n. sp. Busch, Mi 130 (RE).

Crinoids

Crinoid sp. Kindle & Breger, Cumings, LC 190 (RE). Crinoid sp. Kindle & Breger, Cumings, LC 190 (RE). *Eucalyptocrinites crassus* Hall, Sa —20 (IR); LC 192, 320 (RE). *Gissocrinus quadratus*, LC 220 (RE). *Gissocrinus* cf. *G. quadratus*, LC 235 (IR). *Pisocrinus* sp., LC 235, 240± (IR); LC 190 (RE); *Pisocrinus baccula*, LC 235 (IR). *P. benedicti* Miller, Mi 205, LC 240± (IR); LC 190 (RE). *P. campana* Miller, LC 240± (IR); LC 220, 310 (RE). *P. gemmiformis* Miller, LC 235, 240± (IR); *P. gorbyi*, Mi 205, LC 235, 240± (IR). *P. quinquelobus*, LC 235 (IR).

Cystoids

Caryocrinites ornatus Say, LC 320 (RE).

Trilobites

Bumastus sp., LC 185 (RE). *B. armatus* (Hall), Lo 76, LC 350 (RE). *B. cuniculus* (Hall), Mi 175 (RE). *B. insignis* (Hall), Lo 75 (IR); Lo 76, Mi 85, 140, 175, LC 191, 192, 350, 370, 375 (RE). *B. ioxus* (Hall), Sa —35 (IR); Mi 115, 170, LC 190, 191, 192, 310 (RE). *B. niagarensis* (Whitfield), Lo 76 (RE). *Calymene niagarensis* Hall, Sa —80, Lo 75, Mi 205, LC 240± (IR); Mi 130, LC 190, 220, 320 (RE). *C.* cf. *C. vodgei* Foerste, Mi 130, LC 185, 190, 208±, 220, 350 (RE). *Ceratocephala goniata* Warder, Mi 115 (RE). *Cheirurus niagarensis* (Hall), LC 205 (IR); Lo 76, Mi 85, 130, LC 192, 205, 350 (RE). *Dalmanites* sp., Sa —10 (IR); LC 320 (RE). *D. vigilans* Hall, Lo 76, Mi 120, 210± (IR); Mi 115, 130, LC 191, 220 (RE). *Encrinurus* sp., Mi 130, 175, LC 220, 350 (RE). *E. indianaensis* Kindle & Breger, Sa —80, Lo 76, LC 225 (IR); Mi 130, 140, LC 185, 190, 191, 192, 310, 370, 375 (RE). *E. ornatus* Hall & Whitfield, Mi 140 (RE). *B.* cf. *B. insignis* (Hall), LC 190 (RE). *Illanus* sp., LC 310 (RE). *Odontopleura* sp., LC 185 (IR). *O. orton* (Foerste), Mi 115, LC 350 (RE). *Phacops pulchellus* Foerste, Sa —30 (IR); LC 192, 350 (RE). *P.* cf. *P. pulchellus* Foerste, Mi 120 (IR); Mi 115, LC 191, 192, 350 (RE). *Proteus* sp., Lo 75, LC 225 (IR). *Sphaerexochus romingeri* Hall, Mi 130, 140, LC 191, 192, 220, 240, 350, 370, 375 (RE).

¹ Interrelationships of stratigraphic units are shown in Figure 2. Abbreviations: Sa, Salamonie Dolomite; Lo, Louisville Limestone; Mi, Mississinewa Shale Member of Wabash Formation; LC, Liston Creek Limestone Member of Wabash Formation. Figures following the stratigraphic designations refer to approximate distance above the base of Waldron Formation; also, they are keyed to geographic position through Appendix 2. Abbreviations (IR) and (RE) following stratigraphic designations refer to interreef or nonreef (IR) and reef (RE) facies, respectively.

APPENDIX 2

Collection sites, stratigraphic levels, and literature sources for subgeneric taxa of Niagaran (middle Silurian) macrofossils of northern Indiana.¹

Adams County

30²; Linn Grove, Meshberger Bros. quarry, SE $\frac{1}{4}$, Sec. 33, T 26 N, R 13 E; I. Lo Ir³; 30; B⁴. 32; New Corydon northwest, Smith & Baker abandoned quarry, SW $\frac{1}{4}$, Sec. 32, T 25 N, R 15 E; U Sa Ir; —25; B, C, C&S. 31; New Corydon west, J. W. Karsch quarry, SW $\frac{1}{4}$ SW $\frac{1}{4}$, Sec. 31, T 25 N, R 15 E; U Sa Ir; —30; B, C, C&S.

Allen County

24; May Stone & Sand, Inc., Ardmore Quarry, C N $\frac{1}{2}$, Sec. 29, T 30 N, R 12 E; U Lo Ir; 100; Sh (a), Sh & O.

Carroll County

4; Camden southeast and Little Deer Creek, NW $\frac{1}{4}$ NW $\frac{1}{4}$, Sec. 30, T 25 N, R 1 E; U Wa Re; 370; C&S, K&B. 3; Delphi, Secs. 19, 20, 29 and 30, T 25 N, R 2 W; U Wa Re; 375; C&S, F, K&B, Sa, T&C.

Cass County

2; Georgetown east, reef, Sec. 36, T 27 N, R 1 W; M Wa Re; 350; C&S, K&B, L(b).

Delaware County

43; Muncie City, Sec. 10?, T 20 N, R 10 E; L Mi Ir or U Lo Ir; 90; C&S. 42; Muncie southwest, Muncie Stone Co. or J & K Stone Co. quarry, C, Sec. 20, T 20 N, R 10 E; U Lo Ir; 75; C&S. 41; Yorktown northeast, abandoned quarries, NW $\frac{1}{4}$ SW $\frac{1}{4}$, Sec. 14, T 20 N, R 9 E; At Lo-Mi boundary in Mi Ir; 76; C&S.

Grant County

34; Marion, in or near, T 24 and 25 N, R 8 E; U Mi Ir; 205; C&S, K&B.

Hamilton County

39; Fall Creek north side, formerly Helm's Mill, Secs. 5 and 6, T 17 N, R 6 E, Sec. 32, T 18 N, R 6 E; L LC? Re; 170; K&B. 36; Fishersburg southwest, abandoned quarries, E $\frac{1}{2}$, Sec. 29, T 19 N, R 6 E; L LC Re; 191; K&B. 35; White River at Riverwood, formerly Connors Mill, E $\frac{1}{2}$ NW $\frac{1}{4}$, Sec. 16, T 19 N, R 5 E; L LC Re; 192; C&S, K&B.

Huntington County

20; Huntington County west-central, four locations, T 28 N, R 8 E; L LC Ir, 233 $\pm$, Sh(a); L LC Re, 233 $\pm$, Sh(a). 22; Huntington east⁵, abandoned quarries and river channel, Secs. 7, 8, 18, T 28 N, R 10 E, and Secs. 12, 13, T 28 N, R 9 E; L LC Ir; 185; C, C&S, K&B. 21; Huntington, Erie Stone Co. quarry, SE $\frac{1}{4}$, Sec. 12, T 28 N, R 9 E; L LC Ir, 180, C&S, Sa; L LC Re, 180, C&S, Sa. 25; Lancaster south, abandoned quarry, SE $\frac{1}{4}$ SE $\frac{1}{4}$, Sec. 33, T 27 N, R 9 E; U Mi Re; 175; B. 23; Little Wabash River, Secs. 7, 8, 18, T 28 N, R 10 E; L LC Ir, 185, C&S; L LC Re, 185, C&S. 27; Markle south, abandoned quarry, Wildcat Reserve 37, T 27 N, R 10 E; M Mi Re; 130; B, C&S. 26; Warren west, abandoned quarry, W $\frac{1}{2}$ SE $\frac{1}{4}$, Sec. 19, T 26 N, R 10 E; M Mi Re; 140; B.

Jay County

33; Jay City, Sec. 5, T 24 N, R 15 E; U Sa Ir; —20; C&S.

Madison County

38; Anderson west, 1 mile, NE $\frac{1}{4}$ SE $\frac{1}{4}$, Sec. 10?, T 19 N, R 7 E; Mi Ir?; 120; K&B. 37; Lapel, Martin Marietta Central Division quarry, C N $\frac{1}{2}$, Sec. 28, T 19 N, R 6 E; L LC Re; 190; C. 40; Pendleton, Fall Creek, Sec. 20, T 18 N, R 7 E; Mi Re; 115; K&B.

Miami County

8; Mississinewa River at Cliffs of the Seven Double Pillars, S part Reserve 10, T 26 N, R 5 E; LC Ir; 225; C&S. 9; Peoria southeast, Mississinewa Reservoir, Secs. 10 or 11, T 26 N, R 5 E; L LC Re; 240; C&S. 7; Peru city, vicinity Mount Hope Cemetery, Sec. 28, T 27 N, R 4 E; LC Re; 320; C&S. 5; Peru northwest, SW $\frac{1}{4}$, Sec. 20, T 27 N, R 4 E; LC Re; 310; C. 6; Peru southwest, north side Wabash River opposite mouth of Little Pipe Creek, S $\frac{1}{2}$, Sec. 32, T 27 N, R 4 E; LC Ir; 300; C&S.

Randolph County

44; Fairview southeast, quarry, NW $\frac{1}{4}$ SW $\frac{1}{4}$, Sec. 11, T 21 N, R 12 E; U Sa Ir; —10; C&S. 46; Maxville, abandoned quarries, Sec. 20, T 20 N, R 13 E; M? Sa Ir; —80; C&S. 45; Ridgeville east, abandoned quarry, NW $\frac{1}{4}$ SW $\frac{1}{4}$, Sec. 7, T 21 N, R 14 E; U? Sa Ir; —35; B, C&S.

Wabash County

15; General county, mostly? T 27 N, R 6 E; LC Ir and other recks?; 240 $\pm$; C&S, L(a). 18; Hanging Rock, W $\frac{1}{2}$ SE $\frac{1}{4}$, Sec. 35, T 28 N, R 7 E; U Mi and L LC Re; 208 $\pm$; T&C. 17; Lagro, general vicinity, south-central part of T 28 N, R 7 E; U Mi Ir; 200; C&S, K&B; U Mi-L LC Re; 203; T&C. 16; Matlock Cemetery, NE $\frac{1}{4}$ NE $\frac{1}{4}$, Sec. 24, T 27 N, R 6 E; U Mi and L LC? Re; 228 $\pm$; T&C. 10; Red Bridge, Mississinewa Reservoir, S $\frac{1}{2}$ Reserve 26, T 26 N, R 6 E; L LC Ir; 223; C&S; U Mi Ir; 218; C&S. 14; South Wabash Reef, NE $\frac{1}{4}$ Reserve 18, T 27 N, R 6 E; U Mi-L LC Re; 230; L(a). 11; Wabash city in or near Sec. 10, T 27 N, R 6 E; L LC Ir; 215; C&S; U Mi Ir; 215; C&S. 19; Wabash County east-central, 13 locations, T 27 and 28 N, R 7 and 8 E; U Mi Ir; 210 $\pm$; Sh(a); L LC Ir; 210 $\pm$; Sh(a); L LC Re, 210 $\pm$; Sh(a). 12; Wabash Reef, C SE $\frac{1}{4}$ SE $\frac{1}{4}$, Sec. 11, T 27 N, R 6 E; U Mi-L LC Re; 220; C&S, K&B, L(b), T&C. 13; Wabash south, State Highway 15 road cut?, N $\frac{1}{2}$ Reserve 18, T 27 N, R 6 E; L LC Ir; 235; L(a).

Wells County

29; Bluffton north, Erie Stone Co. quarry, W $\frac{1}{2}$ NW $\frac{1}{4}$, Sec. 28, T 27 N, R 12 E; L Mi Re; 85; B, C&S, T&C. 28; Rockford, abandoned quarry, E $\frac{1}{2}$, Sec. 29, T 27 N, R 11 E; L Mi or U Lo Ir; 105; C&S.

White County

1; Monon south, Monon Crushed Stone Co. quarry, NE $\frac{1}{4}$, Sec. 28, T 28 N, R 4 W; U Wa Re; 425; C&S, K&B, Sh&O.

¹ Sequence is as follows: county, map no., site; location, stratigraphic unit; Waldron datum; literature source, respectively.

² Map numbers are shown in Figure 1.

³ Interrelationships of stratigraphic units are shown in Figure 2. Abbreviations: L, lower; M, middle; U, upper; Sa, Salamonie Dolomite; Lo, Louisville Limestone; Mi, Mississinewa Shale Member of Wabash Formation; LC, Liston Creek Limestone Member of Wabash Formation; Wa, Wabash Formation undifferentiated; Ir, interreef or nonreef; Re, reef or reef flank; Waldron-datum figures give approximate feet above base of Waldron Formation for collection sites, those figures preceded by a minus sign being estimated feet below the now-eroded Waldron at those locations; because of regional differences in deposition and because most figures are estimated, the Waldron-datum figures are not all indicative of the exact order of superposition among the faunas.

⁴ Literature source abbreviations: B, Busch (3); C, Cumings (6); C&S, Cumings and Shrock (8); F, Flower (10); K&B, Kindle and Breger (13); L(a), Lowenstam (14); L(b), Lowenstam (15); P&S, Pinsak and Shaver (19); Sa, Sangree (20); Sh(a), Shaver (21); Sh(b), Shaver (22); Sh&O, Shaver and others (25); and T&C, Textoris and Carozzi (27). Several older references to the fossils and their localities have not been included, the intent here being to give the major and (or) latest sources for all subgeneric taxa of record. Example: Cumings and Shrock and Kindle and Breger are listed as major sources of fossil information for Delphi, but neither pair were the first to record taxa of record. Example: Cumings and Shrock and Kindle and Breger are listed as major sources of fossil information for Delphi, but neither pair were the first to record taxa at that place; Lowenstam is added because a single taxon would not have been documented otherwise.

⁵ It is not clear from Cumings and Shrock (8) that some of the Liston Creek interreef coral species listed in their table came from a location $1\frac{1}{2}$ miles southwest of Huntington (NE $\frac{1}{4}$, Sec. 28, T 28 N, R 9 E). Page 105 of the R. R. Shrock field notebook (deposited in the Department of Geology, Indiana University), however, refers to a fine collection of Liston Creek corals from the southwest Huntington location. Thus, it seems very probable that the coral list for location 22 is a composite for the Huntington area.

HISTORY OF SCIENCE

Chairman: JOHN J. FAVINGER,
Indiana Department of Natural Resources, Indianapolis, Indiana 46204

WILLIAM R. EBERLY, Department of Biology,
Manchester College, North Manchester, Indiana 46962, was elected
Chairman for 1974

ABSTRACTS

Indiana Women in Mathematics. WILLIAM E. EDINGTON, DePauw University, Greencastle, Indiana 46135.—The first earned Ph.D. degrees in Mathematics conferred by both Indiana University and Purdue University were conferred on women. Indiana University conferred its first Ph.D. degree in Mathematics on Cora B. Hennel in 1912. Purdue University conferred its first Ph.D. in Mathematics on Cleota G. Fry in 1939. Cora B. Hennel (1886-1947) taught mathematics at Indiana University from 1908 to 1947 and attained the rank of Professor in 1936. Cleota G. Fry has been a member of the Mathematics Department at Purdue since receiving the doctorate. The first woman to be Head of a Department at a State School in Indiana was Mrs. Lizzie S. Byers who was Head of the Department of Mathematics in the Indiana State Normal School, in Terre Haute, from 1890 to 1893. Mrs. Byers had Elizabeth Long as an Assistant in the Department. Cora B. Hennel was one of the 30 Charter Members from Indiana in the organization of the Mathematical Association of America in December, 1915, with a Charter Membership of 1,045, of whom approximately $\frac{1}{3}$ were women. Four other Indiana women, Juna Lutz Beal, Butler University, Olive M. Draper, Taylor University, Florence Long, Earlham College, and Inez Morris, Indiana State University, have made outstanding contributions to education in Mathematics as Heads of the Departments of Mathematics in their respective institutions.

Indiana Contributions to the National Plant Board. JOHN J. FAVINGER, Indiana Department of Natural Resources, Indianapolis, Indiana 46204. —The National Plant Board (NPB) is a policy making and advisory group of state plant regulatory officials established in 1925. It is a small action group of eight members, two each from the four regional plant boards: The Western, Southern, Eastern and Central. A total of 90 individuals have served on the NPB. The State Entomologist is Indiana's representative to the Central Plant Board (CPB). Frank N. Wallace, State Entomologist 1915-1958 was one of the original members of the NPB and served 1925 through 1927. The incumbent John J. Favinger has been a CPB representative to the NPB for 5 years and is presently secretary-treasurer. Other men who have played an important role were native Hoosiers: Dr. T. J. Headlee, a native of White County, was educated at Indiana State Normal College and Indiana University and while at Rutgers University was instrumental in the formation of the Eastern Plant Board and the National Plant Board,

serving as a representative to the latter from 1937 through 1942. John W. Baringer, long-time Chief of the Division of Plant Industry, Ohio Department of Agriculture, served on the NPB from 1957 through 1960. He was born at Jamestown, Indiana, and graduated from Wabash College in 1918. The 47th annual meeting of the NPB was held at the Speedway Motel, Indianapolis, August 21-23, 1973, marking the first time a meeting of the group had been held in Indiana.

Linnean "Elements" in the Indiana Fauna and Flora

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Abstract

Previous studies have investigated the nature and origins of insect names, particularly folk names of dragonflies and the "insect" generic names of Linnaeus (17, 18, 19).

The Linnean elements (names of genera and taxa of the species-group) of the Indiana Biota were analyzed to determine the numbers and percentages of each group named by Linnaeus. This varies for genera from 62% in plants to 2.0% in dragonflies, and for species from 45.8% in birds (35.0% in plants) to 2.0% in both beetles and dragonflies.

These names of Indiana taxa were used as a basis for a comparison of the differences in the treatment of the names of plants and animals by Linnaeus, and to show the sources of his plant names. Most of these were adopted or adapted from earlier authors, many of them (although, perhaps, not as great a proportion—91%—as his insect names) being classical Latin or Greek words almost identical with those used by Pliny, Theophrastus and Dioscorides. Linnaeus usually gave credit to earlier authors (although, not necessarily to the first, even of late medieval or early modern authors to use them), most frequently to Tournefort, but gave no credit or reference to earlier authors for generic names of animals.

A discussion of insect names, their nature and origins was published previously (18, 19).

The study of Linnean insect names led to an interest in the differences in the origin and treatment of the names which Linnaeus used for plants and animals. For a study of such differences the Linnean taxa listed in two comprehensive state catalogues of roughly comparable size—Deam's Flora (3) and Blatchley's Coleoptera, or Beetles (1) of Indiana were used. However, the study was quickly expanded to other groups for which there are good Indiana lists, dragonflies (16), fishes (4), amphibians and reptiles (15), birds (20) and mammals (14) and to some consideration of all generic names used by Linnaeus in his *Systema Naturae* (11).

A tabulation of the numbers and percentages of the Indiana taxa attributed to Linnaeus is given in Table 1. The proportions of Linnean taxa in plants, vertebrates and insects in that order (except for species of birds) may, indeed, reflect his relative inherent knowledge of these groups. It is also affected, perhaps much more, by the state of knowledge of the different groups at the time, since Linnaeus was primarily an encyclopedist, compiling available information rather than doing original work himself. This knowledge was dependent upon the relative interest and activity of writers and collectors of the several groups. Since there was no biological exploration of Indiana until after the time of Linnaeus, the ranges of the diverse groups were the chief factors determining what would be available to collectors. Linnaeus generated a great interest and collecting activity through his correspondence and by the dispatch of his students to every possible area. No doubt his stimulation of plant exploration was greater than that of animal collection.

TABLE 1. *Numbers of genera and species (including subspecies and varieties) of selected groups of the Indiana Biota, showing the numbers and percentages named by Linnaeus.*

Group	Listed for Indiana					
	Genera			Species, etc.		
	Total	Linnean		Total	Linnean	
		No.	%		No.	%
Plants -----	737	458	62.0	2593	907	35.0
Beetles -----	858	24	2.7	3312	67	2.0
Dragonflies -----	51	1	2.0	148	3	2.0
Fishes -----	94	8	8.5	180	9	5.0
Amphibians -----	15	2	13.5	42	1	2.4
Reptiles -----	34	2	5.9	62	11	17.7
Birds -----	217	28	12.9	358	164	45.8
Mammals -----	67	13	19.4	101	12	11.9

Some people believe that Linnaeus was the first to name plants and animals, at least in any exhaustive manner. A much greater number have the idea that he: 1) invented binomial, *i.e.*, binary or two-word, names (genus and species); 2) was the first to completely classify plants and animals; 3) started the practice of creating names for all groups by compounding words from Latin and Greek roots and affixes; and 4) created an hierarchy of classification (kingdom, class, order, genus, species) and formulated names for all of these groups. None of these are true; yet, his reputation is such that it is sometimes impossible to trace the actual application of ancient names because lexicographers quote him as an authority. It is also difficult or impossible to trace the development of plant and animal names in reference books, even biological dictionaries and encyclopedias, because they start with his classification and nomenclature and discuss the development as if his treatment were the beginning.

Stearn (21) pointed out that binomial names for plants may be found in ancient Greek, Latin, German and English long before they were used by Linnaeus. Furthermore, Kaspar Bauhin, in 1623, published a review of all known plants, about 6,000 species, using a system of classification based upon genus and species, essentially the binomial system. This has been traced back to the ancients, as it is an attribute of the human mind to group like things, then distinguish them from each other. This can frequently be done with only two words.

In his "Historia Generalis Plantarum" in three volumes, from 1686 to 1704, John Ray of England delineated 18,600 plants, giving information on structure, physiology, distribution and habits. The main divisions of classification recognized today were laid out on the basis of a natural system. He did almost as much for animals.

The insect generic names of Linnaeus were largely (91%) Latin and Greek words adopted almost without change, and some of the compounding from roots and affixes can be traced back as far as Sophocles in the 5th Century B.C. (19). Linnaeus named seven orders of insects,

Aptera, Diptera, Coleoptera, Hemiptera, Lepidoptera, Neuroptera and Hymenoptera. These names are elegant expressions of the wing characters and it would seem that he did a fine job in formulating them. However, three, Aptera, Diptera and Coleoptera, were used by Aristotle and Hymenoptera appears in the writing of Strabo (10).

His contemporaries charged Linnaeus with two particular faults (2). Haller, the Swiss naturalist, accused him of trying to be a second Adam and name all plants and animals; and Dillenius, Professor of Botany at Oxford, objected to his system of classification and his use of the Greek names of Theophrastus and Dioscorides. Dillenius noted that the day might come when the plants to which the ancients applied these names would be identified and if the names were used for other plants the confusion would be great.

A later botanist, J. van Sachs, observed that Linnaeus "was content to know all his species exactly by name and never made a single important discovery throwing light on the nature of the vegetable or animal kingdom" (21). Linnaeus, himself, in an autobiographical sketch begun in early life and frequently updated, written in the third person, declared (2): "No one before him had pursued his profession with greater zeal and had more hearers; made more observations in natural history; had fuller insight into the three kingdoms of nature; been a greater botanist or zoologist; so well described the natural history of his own country—its flora, fauna and topography; written more books, more correctly, more methodically, from his own experience; so completely reformed a whole science and inaugurated a new era; sent out his disciples to so many parts of the world; written his name on more plants and insects, indeed on the whole of Nature; become more famous the whole world over; listed so many animals—yes, as many as all the others put to-gether; been a member of more scientific societies." In view of these divergent criticisms and assessments of Linnaeus, one may well ask the true character and value of his contribution to biology. In one sense or another each of the appraisals, including those by himself, is true. While he did not contribute any new discoveries, or even invent any nomenclatural schemes, his compilation and organization of all known species of plants and animals, neatly arranged in a system of categories, instituted a major epoch in the history of biology. The introduction of a uniform scheme of names for known biological units enabled the proper integration of the vast numbers of new plants and animals which were discovered during the century following his work. This era of systematic growth dominated biology until the appearance of Darwin's theory of evolution. The systematic arrangement of living things probably made the discovery of evolution inevitable, although nothing could have been further from the idea and beliefs of Linnaeus.

His first knowledge of the names of plants and their classification came from the works of Tournefort. Probably for this reason he was inclined to use Tournefort's names, attributing to him many which had been in use for a long time, some since antiquity (Tables 2-4).

TABLE 2. *Linnean genera of the Pteridophyta regional to Indiana*¹.

Genus name; technical common	Source of Name as cited by			Origin or derivation of name; gender and meaning or application if a classical word, and citations of ancient authors using it in this sense
	Linn.	Gray	Deam	
<i>Adiantum</i> Maidenhair fern	T	L	T	*(L.). <i>adiantum</i> , N. Pliny.
<i>Asplenium</i> Spleenwort	(L)	L	--	*(L.). <i>asplenium</i> , N. Pliny. *(Gr). <i>asplenon</i> , N. Dsc.
<i>Equisetum</i> Horsetail	T	L	T	*(L.). <i>equisaetum</i> (<i>equus sita</i>), N. Pliny.
<i>Isoetes</i> Quillwort	(L)	L	L	(L). <i>isoetes</i> , N. the small house leek. Pliny. (Gr). <i>isoetes</i> , N. houseleek. Dsc., Thphr.
<i>Lycopodium</i> Clubmoss	(L)	L	L	NL, ex (Gr), <i>lukos</i> , a wolf + <i>pous</i> , foot.
<i>Marsilea</i> Pepperwort	(L)	L	--	A patronymic; named for Aloysius Marsili, Italian naturalist.
<i>Onoclea</i> Sensitive fern	(L)	L	L	ex (Gr), <i>onokleia</i> , F. alkanet, a dye-producing plant. Dsc., Thphr.
<i>Ophioglossum</i> Adder's tongue	T	L	T	NL, ex (Gr), <i>hophis</i> , a serpent + <i>glōssa</i> , tongue.
<i>Osmunda</i> Royal fern	T	L	T	Med.L., ex Saxon, <i>Osmunder</i> , name for the Celtic god Thor.
<i>Polypodium</i>	T	L	T	*(L). <i>polypodium</i> , N. Pliny. *(Gr). <i>polypodion</i> , N. Dsc., Thphr.
<i>Pteris</i>	(L)	L	--	*(Gr.), <i>ptēris</i> , F. Dsc., Thphr.

¹ See Appendix 1.

Linnaeus said that Latin and Greek names were the best and a great proportion of his names, especially those of animals, are just that. This was shown for insects (19) and the same appears to be true for other animals, especially mammals and birds, although no exact percentages have been calculated. As his knowledge of plants was much greater than that of animals, his need for names for plant genera was correspondingly greater. In addition to the adoption of the names of others, and the compounding of some from roots and affixes, he turned to patronymics. He named plant genera for his father-in-law, most of his former teachers, many of his students, famous botanists and many others. No patronymic has been detected among his names for animals.

Linnaeus had no idea of selecting a name on the basis of priority. He merely wanted what he considered the best name. If he found none that satisfied him he selected new ones; his selections were seldom, if ever, without reason. He rejected names with more than 12 letters, those ending in -oidea, obviously double names, etc. It has been those following him who made him the "second Adam" by decreeing through the Codes of Nomenclature that whatever name Linnaeus used would be the name of the plant or animal. Such features of nomenclature were not formulated for over 100 years; the exact dates for such "beginnings" came even later. As shown in the Tables (2-4), the Kew Index (8) cites papers of Linnaeus from 1735 to 1753 for the origin of his generic names. Gray's Manual (5) cites the older authors rather than Linnaeus for the names which he adopted from them. The citation of authors for

these names of Linnaeus has led to the dual system of credit in citing authors in botanical works—Linnaeus and the author from whom he took the name for Linnean genera, and the author of the species name plus the name of the authority who placed it in the genus to which it is assigned for species. This double citation is not followed in zoology. There seems to be much disagreement concerning the pre-Linnean authors to be cited—note the difference between those cited by Linnaeus (12, 13), the Kew Index (8), Gray (5) and Deam (3) as indicated in Tables 2-4. Linnaeus seems not to have gone backward any farther than Tournefort in crediting names, although as indicated in Table

TABLE 3. *Linnean genera of the Gymnospermae and of the Scrophulariaceae recorded for Indiana (Including some not native to the state).*¹

Genus names: technical common	Source of Name as cited by				Origin or derivation of name; gender and meaning or application if a classical word, and citation of ancient authors using it in this sense
	Linn.	Kew	Gray	Deam	
	Ind.				
<i>Abies</i> Fir	T*	T	Link	--	*(L). <i>abies</i> , F. Pliny, Vergil.
<i>Juniperus</i> Juniper	T	T 1735	L	T	*(L). <i>juniperus</i> , F. Pliny, Vergil.
<i>Larix</i> Larch	T*	T	T	T	*(L). <i>larix</i> , F. Pliny. *(Gr). <i>larix</i> , F. Dsc., Pliny.
<i>Pinus</i> Pine	T	T 1735	T	T	*(L). <i>pinus</i> , F. Horace, Ovid, Pliny, Vergil. ex *(Gr). <i>pitys</i> , F. Dsc., H(O), Thphr.
<i>Taxus</i> Yew	T	T 1735	T	T	*(L). <i>taxus</i> , F. Caesar, Ovid, Pliny, Vergil. (Gr). <i>taxon</i> , a bow, for which wood of this was used.
<i>Thuja</i> Arbor-vitae	T	T	--	T	(L). <i>thya</i> (or <i>thya</i>), F. a resinous tree. Pliny. (Gr). <i>thya</i> , F. (same as Latin). Thphr.
<i>Antirrhium</i> Snapdragon	T	T 1735	T	--	*(L). <i>antirrhinon</i> (or <i>--um</i>), N. Pliny. *(Gr). <i>antirrhinon</i> , N. Dsc., Thphr.
<i>Buchera</i> Blue-hearts	(L)	L 1737	L	--	A patronymic, honoring J. G. Buchner, an early German botanist.
<i>Chelone</i> Turtle head	D	L 1735	T	T	(L). <i>chelonum</i> , N. a plant also called <i>cyclaminosa</i> . (Gr). <i>chelônē</i> , F. a tortoise. Hdt., Homer.
<i>Gerardia</i>	P	L 1737	L	L	A patronymic, dedicated to the famous herbalist, John Gerarde.
<i>Gratiola</i>	(L)	R 1737	L	B	NL, ex (L), <i>gratia</i> , grace, or favor, because of supposed excellent medicinal properties.
<i>Linaria</i> Toad flax	T*	T	T	B	(L). <i>linaria</i> , F. a linen factory. Tiro (Cicero's ex (Gr). <i>linon</i> , N. flax. Homer. freedman)
<i>Melampyrum</i>	T	T 1735	T	B	NL, ex (Gr), <i>melas</i> , black + <i>pyros</i> , wheat, from of seeds mixed in the harvested grain.
<i>Mimulus</i> Monkey-flower	L	L 1745	L	--	?ex (L). <i>mimulus</i> , M. (dimutive of <i>minus</i> , an actor), a little actor or mime. (post-classical).
<i>Pedicularis</i> Lousewort	T	T 1735	T	B	NL, ex (L). <i>pediculus</i> , M. a louse.
<i>Scrophularia</i> Figwort	T	T 1735	T	B	NL, ex (L). <i>scrofulae</i> , F. a pathological swelling of glands of the throat.
<i>Verbascum</i> Mullein	T	T 1735	L	B	*(L). <i>verbascum</i> , N. Pliny.
<i>Veronica</i> Speedwell	T	T 1735	L	B	Derivation doubtful (?named for Verona, birth-place of Pliny).

¹ See Appendix 1.

3, Deam cited Bauhin for seven of the generic names in the Scrophulariaceae. An examination of the specific descriptions in the genera *Verbascum* and *Veronica* both of which he attributed to Tournefort, quoted by Linnaeus (12) reveals that he noted the use of both names by Bauhin. Of 27 species of *Veronica*, Bauhin was cited for 18, and 10 of the 18 were described under the name *Veronica*. Of nine species of *Verbascum*, Bauhin was cited for eight with *Verbascum* used for six. It would seem somewhat illogical to cite any of these authors for the origin of the names since most of them were used by ancient Latin and Greek writers—note especially the pteridophytes (Table 2) and the gymnosperms (Table 3). Further study of the information in the tables, particularly of the Scrophulariaceae (Table 3) and the grasses (Table 4), would indicate that Dillenius had a good basis for his charge that Linnaeus was using the names of the ancient authors incorrectly. Of course, the "modern" application of some of the names had been made by earlier authors, whom Linnaeus followed. Also the identity of many of the plants to which the names were applied in antiquity has been irretrievably lost and their use by Linnaeus is not likely to result in any confusion. In at least one case there could be objection to his use of a name, and it could scarcely be excused because of any lack of knowledge of its ancient application. As he wrote in Latin he usually employed Latin names if they were known; thus, his choice of *Ulmus* for the elms would be correct. Never-

TABLE 4. *Linnean genera of the Gramineae (Grass Family) recorded from Indiana, (including some which are found only as "escapes" from cultivation).*

Genus names: technical common	Source of Name as cited by				Origin or derivation of name; gender and meaning or application if a classical word, and citation of ancient authors using it in this sense
	Linn.	Kew	Gray	Deam	
		Ind.			
<i>Aegilops</i>	(L)	L	--	--	(L). <i>aegilops</i> , F. a tare in barley. Pliny.
Goatgrass		1737			(Gr). <i>aegilōps</i> , M. (same as Latin). Dsc., Thphr.
<i>Agrostis</i>	(L)	L	L	L	(L). <i>agrostis</i> , F. a grass. App.Herb.
Bentgrass		1735			(Gr). <i>agrōstis</i> , F. dog's tooth grass. Dsc., H(O).
<i>Alopecurus</i>	(L)	L	L	L	(L). <i>alpecurus</i> , F. a kind of plant. Pliny.
Foxtail		1735			(Gr). <i>alopekoyros</i> , M. bear grass. Thphr.
<i>Andropogon</i>	(L)	L	L	L	NL, ex (Gr), <i>anēr</i> , man + <i>pōgōn</i> , beard.
Beardgrass		1753			
<i>Anthoxanthum</i>	(L)	L	L	L	NL, ex (Gr), <i>anthos</i> , flower + <i>xanthos</i> , yellow.
Sweet vernal grass		1737			
<i>Aristida</i>	(L)	L	L	L	(L). <i>arista</i> , F. awn or beard of grain. Cicero, Ovid.
Three-awn grass		1753			
<i>Avena</i>	T	L	L	L	*(L). <i>avena</i> , F. Horace, Vergil.
Oat		1735			
<i>Bromus</i>	M	D	L	L	(L). <i>bromos</i> , M. oat. Pliny.
Bromegrass		1735			(Gr). <i>bromos</i> , M. oat. Dsc., Hpp.
<i>Cenchrus</i>	(L)	L	L	L	(Gr). <i>kegchros</i> , M. millet. Hesiod, Hdt., Hpp., Thphr.
Burggrass		1737			
<i>Cinna</i>	(L)	L	L	L	(Gr). <i>kinna</i> , N. a kind of barley. Dsc.
Woodreed		1753			

¹ See Appendix 1.

TABLE 4. Continued

Genus names: technical common	Source of Name as cited by				Origin or derivation of name; gender and meaning or application if a classical word, and citation of ancient authors using it in this sense
	Linn.	Kew	Gray	Deam	
		Ind.			
<i>Cynosurus</i>	(L)	L	L	L	NL, ex (Gr), <i>kynos</i> , dog + <i>oura</i> , tail.
		1737			
<i>Dactylus</i>	(L)	L	L	L	(L). <i>dactylus</i> , M. a kind of grass (also a grape).
Orchard grass		1742			Pliny.
<i>Elymus</i>	(L)	L	L	L	(Gr). <i>elymos</i> , F. millet. Dsc., Hpp.
Wild rye					
<i>Festuca</i>	(L)	T	L	L	(L). <i>festuca</i> , F. straw-like weeds which grow in
Fesque grass		1735			barley. Pliny.
<i>Holcus</i>	(L)	L	L	L	(L). <i>holcus</i> , M. a kind of grass (<i>Hordeum</i> sp?).
Meadow softgrass		1735			Pliny.
<i>Hordeum</i>	T	T	T	T	*(L). <i>hordeum</i> , N. Cato, Columella, Livy, Pliny.
Barley		1735			
<i>Lolium</i>	(L)	L	L	L	(L). <i>lolium</i> , N. cockle, or tares. Pliny.
Ryegrass		1735			
<i>Melica</i>	(L)	L	L	L	?ex (L). <i>melica</i> , F. probably a kind of vessel.
Melic-grass		1737			(also this is the Italian name for sorghum, ex <i>mel</i> , honey).
<i>Milium</i>	T	L	T	L	(L). <i>milium</i> , N. ancient name of Millet. Pliny,
Millet grass		1735			Vergil.
<i>Panicum</i>	(L)	L	L	L	(L). <i>panicum</i> , N. Italian millet. Caesar, Pliny.
Panic-grass		1735			?ex (Gr), <i>panikos</i> , adj. of or for Pan; panic; fears.
<i>Phalaris</i>	(L)	L	L	L	*(L). <i>phalaris</i> , F. Pliny.
Canary grass		1735			
<i>Paspalum</i>	(L)	L	L	L	(Gr). <i>paspalos</i> , M. another name for <i>Kengchros</i> ,
		1759			millet.
<i>Phleum</i>	(L)	L	L	L	(Gr). <i>phleōs</i> , M. a kind of reed. Aristotle, Thphr.
Timothy		1735			
<i>Poa</i>	(L)	L	L	L	*(Gr). <i>poa</i> , F. (possibly any grass, or fodder).
Bluegrass		1737			Hesiod, H(O), Hdt., Thphr.
<i>Secale</i>	(L)	T	L	--	*?(L). <i>secale</i> , N. (a kind of grain; rye, or spelt?). Pliny.
Rye		1735			*?(Gr). <i>sēkalis</i> , N?. (possibly derived from Latin).
<i>Stipa</i>	(L)	L	L	L	(L). ex? <i>stipa</i> (correctly <i>stuppa</i>), F. the coarse
Needle grass		1753			part of flax.
					(Gr). <i>stuppē</i> , F., (or <i>stuppion</i> , N.). same meaning as in Latin. Hdt.
<i>Tripsacum</i>	(L)	L	L	L	NL, ex (Gr), <i>tribō</i> , to rub. Perhaps in allusion
Gama-grass		1759			to the polished fertile spike.
<i>Triticum</i>	T	L	--	L	*(L). <i>triticum</i> , N. Caesar, Cicero, Columella,
Wheat		1735			Pliny.
<i>Uniola</i>	(L)	L	L	L	(L). <i>uniola</i> , F. an unidentified plant. App.Herb.
Spikegrass		1737			
<i>Zea</i>	(L)	L	--	L	(L). <i>zea</i> , F. a kind of grain (spelt?). Pliny.
Corn		1737			(Gr). <i>zeia</i> , F. varieties of wheat. Dsc., H(O), Thphr.
<i>Zizania</i>	G	G	G	L	(L). <i>zizania</i> , N. cockle or tares. Ambrose; the
Wild rice, etc.		1742			Vulgate.
					(Gr). <i>zizanian</i> , N. some wild grass, or tares. New Testament.

¹ See Appendix 1.

theless, there seems to be little justification for applying the Greek name *Ptelea*, used as a name of the elm by almost every Greek writer from Homer to Dioscorides, to an entirely different genus, even in a different family!

Linnaeus wrote in Latin because that was the universal language of the universities of his time. His use of it, however, was far from classical, and he virtually created a new language, taxonomic Latin—descriptions in a telegraphic style, almost entirely without verbs, employing only a few nouns and depending chiefly on adjectives. He did retain one feature, gender, which has little intrinsic value to nomenclature, and which is one of the most troublesome problems in nomenclature to the average American biology student today. As gender is an essential property of both Latin and his native Swedish, the thought that it might not be necessary could never occur to Linnaeus.

A comparison of the numbers of genera and species (Table 5) listed in the 1st and the 10th editions of the *Systema Naturae* (11) shows that Linnaeus increased his knowledge greatly between 1735 and 1758/59. Although he was interested primarily in botany he listed only genera of plants in 1735. However, he had a most elegant chart, showing classes, orders, genera and species of animals. A close examination reveals that his actual classification of animals was considerably less impressive than the treatment would indicate. Species names were quite variable in form—one word which was sometimes the same as the genus name, or two words one of which was frequently, but not always the same as the genus name. The development of a true binary nomenclature in his publications came much later, reaching completeness only in 1753 for plants (12) and 1758 for animals (11). Although folk names tend to be single words, or binomials to distinguish related species as pointed out above, rarely trinomials, names had become much longer as the knowledge of plants and animals grew. The naming followed the rule of Aristotle for defining or distinguishing anything—place it in its lowest possible group (genus) and differentiate it from other members of that group (differentia, or specific name). This practice of naming a species—genus plus differentia—had been more or less the practice since antiquity. With the increase in the number of species known the “species names” necessarily became longer. These were the “species names” referred to by Linnaeus when he first formulated his rules of classification. He expressed the opinion that they should not exceed 12 words in length! Heller (7) suggested that the adoption of a two-word name by Linnaeus was not a direct development from the frequent use of such names in the past. It was adapted from the type of citation he used for literature in his publications almost from the beginning.

Many of the “trivial names” (so-called since the differentia were still referred to as the true specific names) of plants were selected from some feature of the specific discussion—a word from the differentia, one referring to habitat, locus (country), etc. Others were obtained from various other sources. Frequently the names of genera placed

in synonymy by Linnaeus were used for trivial names—*Tulipifera* of Catesby became a species of *Liriodendron*, *Blatteria* of Bauhin one of *Verbascum*, and *Chamaedrys* Bauhin (in which several species had been placed) and *Bonatotia* Micheli both were made species of *Veronica*. The common American corn was named *Mays* by Tournefort, but suppressed by Linnaeus in favor of *Zea*, and used as the trivial name.

TABLE 5. Numbers of genera and species of different groups listed by Linnaeus in the first (1735) and tenth (1758-59) editions of *Systema Naturae*.

	Edition 1. 1735 ¹		Edition X. 1758-59		
	Genera	Species	Genera	Species	Varieties ²
"Vegetabilia" ----- (Plants)	767	---	1174	6698	--
"Animalia" ----- (Animals)	191	534	312	4289	--
Mammalia -----	33	94	39	186	33
Aves -----	47	116	63	544	25
Amphibia -----	4	27	16	216	5
Pisces -----	41	148	51	378	3
Insecta -----	47	93	74	2031	--
Coleoptera -----	23	32	25	594	--
Hemiptera -----	7	13	8	197	--
Lepidoptera -----	9	22	3	535	--
Neuroptera -----			6	60	--
Hymenoptera -----			8	229	--
Diptera -----			10	188	--
Aptera -----	8	26	14	228	—
Vermes -----	19	64	69	934	27

¹ Species of plants were not listed in the first edition.

² Varieties were not counted in some groups as they were inconspicuously indicated and counting them was difficult.

³ In the first edition the Insecta were divided into four orders and the genera later placed in the Lepidoptera, Neuroptera, Hymenoptera and Diptera were called Angioptera.

The specific names chosen by Linnaeus for animals were more varied than those for plants. For mammals there were frequently enough classical names for both genus and all of the species. The Latin name *Felis* was selected for the genus of "cats", another, *catus*, for one species, and most of the other species had Latin or Greek names which he used—*leo*, *tigris*, *pardus* and *lynx*. Only 465 different names were used for the 544 species of birds listed in 1758, as some names were used several times. Some were classical names of mythological characters, others names of other birds and animals. Most appear to be adjectives, indicating country or region as *orientalis*, *lapponica*, *canadensis*, habitat as *montana*, *sylvatica*, *alpina*, color as *alba*, *chloris*, *fuscus*, anatomical features as *cristus* (used 11 times), *curvirostra*, etc. In the Insecta, names of all the types previously mentioned were used, sometimes after some method, but usually indiscriminately mixed. Heller (6) published an excellent analysis of the use of mythological names in the genus *Papilio*. Names of individuals of groups, as "Trojan and Greek horsemen", the nymphs, the graces,

the muses, the Argonauts, etc., were used for species of the systematic groups of the genus. However, the animal names of Linnaeus have been studied far less than his plant names and many interesting areas probably remain to be explored.

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APPENDIX 1

Explanation of Tables 2-4

Tables 2-4 summarize information concerning the origin and/or derivation of the names of genera of selected groups of Indiana plants.

The four (three in Table 2) columns headed "Source of names as cited by" indicated the author to whom the name is attributed by the authorities named—Linn (11, 12, 13), Kew Ind (8), Gray (5), and Deam (3). The authors are indicated by initials: B—Bauhin, D—Dillenius, G—Gronovius, L—Linnaeus, P—Plumier, R—Royen and T—Tournefort. The Kew Index and Deam follow the Code of Nomenclature in considering "valid" naming of plants to begin with Linnaeus but use the "double" credit as described elsewhere in this paper. However, the Index cited eight different Linnean papers, published from 1735 to 1759, as valid sources for establishment of the several names. Gray did not use double credit and appears to have considered some names to have been established by Tournefort. Linnaeus did not indicate in any manner the names which he originated; those for which he cited no other author are considered to be his and are so marked, "(L)". Initials starred (*) in the column headed "Linn" identify names which Linnaeus synonymized, but were "resurrected" (or validated) by later authors.

Some of the information on the sources and significance of the names was obtained from Gray's Manual (5). The etymology, ancient meanings, gender, and authorities (ancient authors who used the words; only the most familiar are cited) were compiled, or checked, from the classical dictionaries (9, 10). Starred (*) derivations indicate names which appear to have been applied to the same plants in antiquity as now. Abbreviations: Gr—Greek, L—Latin, Med. L.—Medieval Latin, NL—Neo-Latin ("New Latin"); F—feminine, M—masculine, N—neuter; App.Herb.—a 4th Century (A.D.) Herbal erroneously attributed to Lucius Appuleius, a 2nd Century writer, Dsc.—Dioscorides, Hdt.—Herodotus, H(O)—Homer in the Odyssey, Hpp.—Hippocrates, Thphr.—Theophrastus.

Creationism in the Twentieth Century

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Abstract

The question of the origin of living things is a discussion by two groups of scientists. The statements of famous men, such as Henri Fabre, Wilhelm Johannsen and William Bateson stirred up interest, making the decade 1920 to 1929 outstanding. Two leaders were G. M. Price and W. J. Bryan. Organizations were formed, including the Evolution Protest Movement, the American Scientific Affiliation, the Bible-Science Association, and the Creation Research Society.

It may be of value for one who has lived through all of the 20th Century so far to recount his own experiences and observations along with certain notable discoveries in this period.

At the beginning of the 20th Century, evolution, in the United States, was a subject for university professors and theologians; very few others. The doctrine, then 41 years old, counting from Darwin's *Origin of Species*, had not yet appealed to the common man.

School books did not discuss the origin of the earth or of living things. The authors did not mention divine creation or materialistic theories of beginnings but ignored both of them, taking an agnostic position.

Ideas Held Over

Coming now to the beliefs of scientists at the turn of the century, we note certain beliefs of the 19th Century which still were in vogue. Among these were the inheritance of acquired characters and recapitulation in embryos. Spontaneous generation, after two centuries of struggle against disproof by Francesco Redi (1626-1698), Louis Joblot (1645-1723), and Joseph Lister (1827-1912) had finally been laid to rest by Louis Pasteur (1822-1895) in the latter part of the 19th Century (1). Even now, however, there is a desperate struggle to resurrect the theory of life arising of itself. This effort is made by persons who find it hard to prove evolution, or even to visualize it, without spontaneous generation.

Characters of living things acquired through the environment or use or disuse are recognized but they are not transmitted to the following generation (8). This is now recognized even in Russia, where a few decades ago a group with political backing held out for the theory. As for embryos going through the stages of their supposed ancestors, the idea has been dropped by both creationists and evolutionists (3). The demise of spontaneous generation, acquired characters, and recapitulation has made evolution harder to believe.

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Hero Worship

Evolution, however, the doctrine that life arose by chance and developed complexity by material forces, is not science but a type of natural philosophy. Science consists of facts but natural philosophy persists in spite of facts if it satisfies the desires of people about the nature of the world. The man who faced the scholars and theologians and changed the world view of the majority, easing their responsibility to God, became, and is, a hero.

When Gregor Mendel read his paper on inheritance in peas before the Natural Science Society of Brunn in 1865, the minutes of the meeting record that there was no discussion. The minutes record further that later in the evening, Alexander Makowsky mentioned "with the utmost enthusiasm" a book written by an Englishman named Darwin 6 years previously, called *The Origin of Species* (2). The group discussed this book the balance of the evening and all of Europe did the same the rest of the century. Since 1900 however, Mendel's influence has been tremendous.

It is true that Mendel's paper was published in an obscure journal and that he had but little time for research after he was elected administrator of the monastery where he lived. But the real hindrance was that scholars had accepted the assumption that life arose and developed by natural means, and they were looking for the methods involved.

Genetics versus Evolution

The first decade of the 20th Century was a time of great strides in genetics and cytology. Alfred Russel Wallace, Darwin's close friend and co-worker, said, "On the general relation of Mendelism to evolution, I have come to a very definite conclusion. That is, that it is really antagonistic to evolution" (4). William Bateson (1861-1926) said at the American Association for the Advancement of Science at Toronto: "It is impossible for scientists longer to agree with Darwin's theory of the origin of species. No explanation whatever, after forty years, no evidence, has been discovered to verify his genesis of species, . . . We no longer feel as we used to do, that the process of variation, now contemporaneously occurring, is the beginning of a work which needs merely the element of time for its completion: for *even time can not complete that which has not yet begun*" (5).

Along with this frank statement Bateson gave reason to believe that he still had faith in evolution and hoped some method of its occurrence would be found.

A Great Decade

The statement by this great and honest geneticist, December 21, 1921, along with others resembling it, gave a great impetus to the creationist movement in America. The decade, 1920-1930, was a time of marked and noisy protest of the common people against evolution. It was somewhat like the present movement, yet with a different flavor.

The leaders were mostly Christian ministers who were not highly trained in theology. They did well in giving full credit to the Bible but in criticising evolution they downgraded science as well. A common slogan was, "It is better to know the Rock of Ages than the ages of the rocks." Our present creationism gives due credit to a careful study of science and makes a cleavage between science and evolution, calling the latter a natural philosophy.

I remember only two outstanding leaders of this decade: William Jennings Bryan and George McCready Price. The former was well educated, although not in science, was three times nominated for the Presidency by the Democratic Party, and served as Secretary of State under Woodrow Wilson. As an orator he seldom has been equaled.

G. M. Price was born in Canada, was well educated in languages and philosophy, and taught in several colleges. Through his long life he studied the history of science and reports of geologic exploration, wrote a number of books, and contributed much to the creation movement. Although accused of belonging to no scientific society, he was a member of the AAAS and the California Academy of Science. Price was criticised sharply, just as any one else is likely to be who finds fault with a "sacred cow".

The protest of the twenties was directed against those who taught evolution, and Tennessee passed a law against such teaching in the public schools. Arkansas and Mississippi did so later.

The trial which was held at Dayton, Tennessee, in 1925 to test the law has received much publicity. A teacher, John T. Scopes, was persuaded by George Rappleyea, a member of the Civil Liberties Union, to say that he had taught evolution, although he did not remember having done so (6). When W. J. Bryan decided to go to help the prosecution he asked Price to go to help him, but the latter declined because of making a trip to Europe. Bryan had not tried a case in court for 20 years and was in poor health, as evidenced by the fact that he died a few days after the trial.

The three laws against evolution mentioned above have been repealed. A more modern thrust is the ruling of the California Board of Education that where evolution is taught, creation also shall be presented as an alternative theory. Other states, notably Texas, are seeking similar rulings and Tennessee has made such a ruling as a law.

Great Men Help Creationists

All through the 20th Century the evolutionists claimed that no educated scientist has believed in divine creation, but the charge is not true. Henri Fabre (1825-1915) a French entomologist, spoke very clearly against evolution. He was well educated but preferred to live simply, devoting himself to his research and writing. Fabre stressed the importance of intelligent design in living things, and that an adaptation must be fully formed and able to function well the first time rather than accruing gradually (10).

Another very able biologist was Wilhelm Johannsen of Denmark (1857-1927). While his actual beliefs are hard to find, his discoveries disclosed the limits of selection. Johannsen found that large beans when planted usually yield large beans, just as one would expect. But narrowing his research, planting separately large and small beans which had descended from the *same plant*, there was no difference in the size of the progeny (9). Selection, Darwin's pet method, was not effective in this case. These results, obtained about 1909, have been repeated by other workers and in other species, with the same results.

Trained as I was by my study to believe that the greater the selection, the greater the improvement, these results were quite a blow to me. Johannsen taught us that selection merely sorts the genes and becomes ineffective when the genes are all alike, even though there may be differences due to environments.

James D. Watson and F. H. C. Crick, in their work which showed the gene to be very complex, and that the trait to be transmitted depends upon a code, have made it hard to believe in development by chance (7). The code resembles a word and its formation is by choice of clumps of atoms, very much as a word is formed by proper sequence of letters. Codes never have been formed without intelligence.

It is recognized that the proof or disproof of evolution comes from genetics and geology. The former has been discussed above. The developments in geology have been disappointing to evolutionists in that the gaps between the categories of fossils have not been filled. Just in living things, the orders, classes, and phyla have no plant or animal forms to bridge the gaps between them. Likewise, after much patient search, no undisputed fossils have been found beneath the Cambrian rocks. These negative results make it easier to go back to the Biblical account of a general creation in the beginning. In "Urban Geology" a practical turn is developing which is of more value than speculating on the age of fossils.

Creationists Organize

Seeing the discrepancy between the claims of evolutionists and the scientific facts, creationists were made bold to band themselves together to establish their views. At present there are coming to be many organizations, and only a few will be mentioned.

The Evolution Protest Movement of England is one of the early organizations and has had some good scientists as members. A noted one was Douglas Dewar, an ornithologist who lived in India a long time.

The American Scientific Affiliation was formed in 1941 by one man inviting five scientists to come together while he paid their expenses. Many creationists having scientific training were attracted and became members. After a few years the statement of belief was liberalized to attract more members and the thrust against evolution was lessened. The subjects chosen for discussion thereafter were the present needs of society.

The Christian Evidence League of Malverne, New York, arose in 1946. The League publishes *The Creationist*.

In 1963, at a convention of the American Scientific Affiliation and the Evangelical Theological Society, at Wilmore, Kentucky, a group of interested persons worked on the first draft of the Statement of Belief for the new Creation Research Society. The growth of the organization has been much greater than we expected.

The Bible-Science Association with headquarters at Caldwell, Idaho, was formed in 1964. Its strong features are the publishing of a newspaper and selling a wide variety of creationist literature. This organization called a 4-day meeting of all creationist groups at Milwaukee, October 10 to 13, 1972, which was well attended and set a milepost of progress.

In conclusion, let us consider how the characteristics of the present decade, 1963 to 1973, are unique. The century-old discussion has been called the disagreement between scientists and religionists; but as a news writer has well stated, the present argument is between two groups of scientists. Although educated leaders were scarce in the 1920 decade, we now have them by the hundred; the outstanding creationists today are scientists. Many of them are young men and women who have detected for themselves the mistakes in evolution, and see that divine creation is a more valid world view.

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A. B. Ulrey: Pioneer Biology Teacher at Manchester College 1894-1900

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Abstract

Albert Brennus Ulrey, long known as A. B. Ulrey, established the first biology department at Manchester College in 1894 when the college was only 5 years old. Ulrey studied at Indiana University under Jordan and Eigenmann. As might have been expected, his major interest was ichthyology. He studied at some of the major marine laboratories in Europe as well as at Woods Hole. After leaving Manchester College in 1900, he attended Rush Medical School for a year and then took up work at the University of Southern California until his retirement in 1929. He founded the Venice Marine Biological Station and served as its director for many years. Because of his early leadership, the biology department at Manchester College continues strong in the tradition of research, field work and medical preparation.



FIGURE 1. Left—A. B. Ulrey in 1892 while a student at Indiana University. Right—A. B. Ulrey in 1920 at the height of his career at the University of Southern California.

Albert Brennus Ulrey, first biology instructor at Manchester College, was born in North Manchester, Indiana, December 31, 1860. After a short course at the Central Normal College, Danville, Indiana, and a graduate course at the State Normal School, he spent 2 years teaching in the public schools. Then at Indiana University he received both the Bachelors degree (1892) and the Masters of Arts degree (1894). He was on the staff at Indiana University as a zoology instructor from 1892-1894. In the summer of 1894 he traveled extensively in Europe, visiting many educational and scientific institutions, including the well-known zoological station at Naples (1).

In 1894 A. B. Ulrey joined the faculty of Manchester College as the science instructor. Manchester College as an institution had its beginning *ca.* 1860 in Roanoke, Indiana, as the Roanoke Classical Sem-

inary, sponsored by the United Brethren church. In 1889 the institution moved to North Manchester and became Manchester College. The Church of the Brethren bought the facilities from the United Brethren in 1895 and has operated Manchester College since that date.

Professor Ulrey remained with the faculty for several years after the college ownership changed hands. Though Professor Ulrey was a member of the United Brethren church, his parents were members of the (then) German Baptist Brethren, the name changing to the Church of the Brethren in 1908. In 1895 the college faculty consisted of about 10 persons, with Ulrey teaching all the science. During his tenure at Manchester College, Ulrey served as secretary of the faculty.

A. B. Ulrey was a member of the Indiana Academy of Science from 1891 to 1905, publishing 11 papers and abstracts in the *Proceedings of the Indiana Academy of Science*. He made extensive collections of the flora and fauna of Wabash County and surrounding areas. Much of this material was used in his teaching and some is still extant. In the herbarium at Manchester College are 275 specimens collected and prepared by A. B. Ulrey, mostly from Wabash and Kosciusko counties in Indiana but also including 11 specimens from Woods Hole, Mass., two from Niagara Falls and one from Oswego, N.Y. A large collection of bird study skins is now on indefinite loan to Purdue University.

In 1891 he published a prospectus for the establishment of a "Wabash County Science Club". Section 2 of the proposed constitution states that "The objects of the Club shall be: (a) Scientific research with special reference to Wabash County; (b) To stimulate an interest in the study of nature." The roster of membership lists 21 persons, including L. O. Dale, county superintendent of schools, and D. N. Howe, first president of Manchester College. A meeting of November 29, 1890, reported in the flyer lists papers on the Venus's fly-trap, the finches (*Fringillidae*) of Wabash County, the Coddling Moth, Types of the Sternum of Birds, and Reproduction of Mosses, among others. On January 10, 1891, President David Starr Jordan of Indiana University presented an "informal address" to the club. To the best of my knowledge, the Science Club never became a "going" organization and apparently was highly dependent on the personal involvement of Professor Ulrey.

Professor Ulrey was a very well-liked teacher, popular with the students and quite capable as a speaker. The titles of at least three of his addresses are known. On June 13, 1894, he addressed the Young Men's Christian Association (while he was still at Indiana University) on the theme, "Carnal Mindedness". In the spring of 1897 he addressed the Manchester College chapel session on "Health and Diseases". Later he talked to the Bible Society on the subject, "The Value of Scientific Study to Religion".

In his ordinary contacts with students, he was quiet and unassuming. Edward Kintner, long-time teacher at Manchester College and a student of A. B. Ulrey in 1899, recalls that "he was not especially

talkative . . . his voice was rather quiet, he rarely raised it to any extent at all . . . he would give you the impression of somebody who wasn't at all in rugged health". He suffered from T.B. and had had a lung removed. Otho Winger, president of Manchester College for 30 years, says that Ulrey almost quit school in his early days because of his health problem (2).

With his excellent scientific training at Indiana University under David Starr Jordan, Carl Eigenmann, and others, he brought the best of the modern scientific research and teaching to Manchester College in 1894. He offered courses in Geography, Physiology, Geology, Physics, Chemistry, Elementary Zoology, Morphology of Vertebrates, Histology and Microscopical Technique, Embryology, Elementary Botany, Morphology and Classification of Phanerograms, Plant Histology and Microscopical Technique, and a Biological Seminary (=Seminar). Quite an achievement for a one-man department. The following description of the biological laboratory, taken from the catalog of Manchester College for 1895, illustrates the extent of equipment and range of specimens he used in his teaching:

The Biological Laboratory is equipped with all the necessary apparatus and reagents for carrying on advanced work as well as the more elementary. The ordinary reagents for work in histology and embryology are supplied to the student. The department is furnished with a Minot microtome; a good grade of microscopes, one of Bausch and Lomb's C C 4 latest continental pattern with Abbe substage condensor and accessories; Abbe camera lucida, stage and ocular micrometer; apparatus for photomicrography, including camera, photographic outfit, bulls-eye condenser, etc.

The laboratory is supplied with an abundance of alcoholic material for dissection and study (both plants and animals) covering all the marine forms in the courses besides a considerable number for comparative study. For purposes of microscopic demonstrations and study, there are about 500 slides prepared illustrating a wide range of subjects of histology, embryology and general morphology.

There are over a thousand skins of mammals and birds, about two hundred of which are mounted specimens. . . . The fishes are represented by about twelve hundred alcoholic specimens. The Batrachians and Reptiles by about five hundred. Among the less common fishes are the shark, flounder, lancet, lamprey, (sic) etc.

The herbarium contains about twelve hundred specimens. A considerable number of the rarer plants are represented. The sea weeds are represented by alcoholic material. A fairly complete collection of the vertebrates and flowering plants of Wabash County has been arranged in systematic order.

For four summers while he was at North Manchester (1895-98), Ulrey taught in the summer school of Indiana University at their Biology Station at Winona Lake, Indiana, just 20 miles from Manchester College. In 1900 he left Manchester College and studied at Rush Medical College, Chicago, for a year. He also had work at the Northern Illinois College of Ophthalmology. In the fall of 1901 he assumed a position at the University of Southern California where he remained until his retirement in 1929.

His major work in California was in zoology with special emphasis on ichthyology and marine biology. He founded the Venice Marine Biological Station in 1910 and was its director for some time. Major

laboratory and aquarium facilities were dedicated in 1911. Ulrey designed and had built a research launch, the *Anton Dohrn*, which was 35 feet long. The laboratory and aquarium facilities were completely destroyed in a disastrous fire on December 21, 1920. The program of the Venice Biology Station has been continued as the Allan Hancock Foundation.

In California, Ulrey continued his research on marine fishes, starfishes of the California coast, and on the embryology of certain marine worms. At least 22 titles are known to have been published by him. Besides his early membership in the Indiana Academy of Science, he was a member of the American Association for the Advancement of Science, the Southern California Academy of Science, American Eugenics Society, Sigma Xi, and Phi Kappa Phi. He died in 1932.

It is indeed significant that at a time when most of the teachers at Manchester College had little advanced training, Ulrey, the science teacher, should have had such an extensive training and experience with the outstanding scientists of his day. This had a considerable impact on his students. Jerome Isenbarger says, "I consider him one of the most forceful teachers I have ever had. I consider him in the same class with John M. Coulter and David Starr Jordan." E. E. Frantz said, "He was an ardent disciple of the Agassiz-Jordan-Coulter field and laboratory methods of Biological study and research, all of which was so dominant in his service at M.C. Very few small college and academies in the 1890s were so fortunate as to have so well prepared and capable a biology instructor as M.C. had in the life, character and service of A. B. Ulrey." Kintner said, "He was very well liked by his students . . . some were quite devoted followers of his". Besides these three Ulrey students who became biology teachers, one could mention also George W. Tannreuther, who received his A. B. from Manchester College in 1900 with advanced degrees from Antioch College and the University of Chicago, who was for years Professor of Zoology at the University of Missouri. Tannreuther was also a research zoologist with a number of published papers to his credit.

The scientific traditions of Ulrey have been continued at Manchester College, chiefly through one of his students, Edward Kintner, professor of science and biology at Manchester College from 1911 to 1951. During much of this period Kintner was joined by Oscar W. Neher. The scientific tradition could be characterized by a strong emphasis on direct study of actual specimens, field study experiences, involvement in research and publication and participation in scientific organizations and meetings, a heavy emphasis on the health sciences and pre-medical training, and a unique way of relating scientific training and one's religious involvement and commitments. The present biology faculty at Manchester College continues to have a high interest and commitment to these principles and traditions.

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APPENDIX 1.

Publications of Albert Brennus Ulrey

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1. 1891. A review of the Embiotocidae. Proc. Indiana Acad. Science for 1891, p. 176 (abstr.).
 2. 1892. Notes on the American Bittern (*Botaurus lentiginosus*). Ornithologist and Oologist 17:76-77.
 3. 1893. On the fishes of Wabash County. Proc. Indiana Acad. Science for 1893, p. 229-231.
 4. 1893. On some South American Characinidae. Proc. Indiana Academy Science for 1893, p. 226 (abstr.).
 5. 1893. On the occurrence of Kirtland's warbler (*Dendroica kirtlandi* Baird) in Indiana. Proc. Indiana Acad. Science for 1893, p. 224-225.
 6. 1894. Preliminary descriptions of some new South American Characinidae. Amer. Natur., July 1, 1894, p. 610-611.
 7. 1894. Birds of Wabash County. Proc. Indiana Acad. Science for 1894, p. 80 (title only). (with W. O. WALLACE).
 8. 1894. On the occurrence of the whistling swan in Wabash County. Proc. Indiana Acad. Science for 1894, p. 80 (title only).
 9. 1894. The flowering plants of Wabash County. Proc. Indiana Acad. Science for 1894, p. 66 (title only). (with J. N. JENKINS).
 10. 1894. Preliminary account of the development of Etheostoma. Proc. Indiana Acad. Science for 1894, p. 135 (title only).
 11. 1895. Contributions to the biological survey of Wabash County. Proc. Indiana Acad. Science for 1895, p. 147-148.
 12. 1895. Birds of Wabash County. Proc. Indiana Acad. Science for 1895, p. 148-159 (with WILLIAM O. WALLACE).
 13. 1896. On the occurrence of the Russian thistle (*Salsola Kali Tragus*) in Wabash County. Proc. Indiana Acad. Science for 1896, p. 224 (abstr.).
 14. 1896. The increasing abundance of the Opossum (*Didelphis virginiana* Shaw) in Northern Indiana. Proc. Indiana Acad. Science for 1896, p. 279 (abstr.).
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Note. In addition to the above, numerous reports of the work of the Venice Marine Biological Station were written by A. B. Ulrey and appeared in various numbers of the *Bulletin of the University of Southern California* between 1910 and 1920. Other publications of Ulrey may come to light with further study. The writer would appreciate knowing of any not included in the above listing.

MICROBIOLOGY AND MOLECULAR BIOLOGY

Chairman: MORRIS POLLARD, Department of Microbiology,
University of Notre Dame, Notre Dame, Indiana 46556

RALPH L. NICHOLSON, Department of Botany and Plant Pathology,
Purdue University, West Lafayette, Indiana 47907,
was elected Chairman for 1974

ABSTRACTS

Therapy of Leukemic AKR Mice by Allogeneic Bone Marrow Transplantation. ROBERT L. TRUITT and MORRIS POLLARD, Lobund Laboratory, University of Notre Dame, Notre Dame, Indiana 46556.—AKR mice develop spontaneous lymphatic leukemia at average age of 8 months (range 3-13 months) and rarely survive for 10 days after the appearance of symptoms. We have reported previously that mice with allogeneic bone marrow chimerism survived as long as they remained germfree (Rad. Res. 45:577, 1971); and that germfree AKR mice with DBA/2 bone marrow cells did not develop spontaneous leukemia if transplanted when 11 weeks old (Proc.Soc.Exp.Biol.Med. 144:659, 1973). In this report, allogeneic bone marrow transplantation was applied to AKR mice with advanced stages of leukemia in an effort to "cure" the disease. Leukemic mice were obtained from our germfree and conventional colonies, or they were conventional mice which had been decontaminated through an antibiotic regimen. Immediately after diagnosis of leukemia, the AKR mice (H^{-2k}) were administered 850 or 1000R X-rays (whole-body) and 24 hours later injected with at least 10^7 viable bone marrow cells from DBA/2 mice (H^{-2d}). The results show that while untreated leukemic AKR mice died within 2 weeks after diagnosis, germfree and decontaminated, chimeric AKR mice survived longer than 90 days. These mice remain under observation. Conventional counterpart chimeras died of secondary disease within 60 days. Thus, allogeneic bone marrow cells have therapeutic value for the treatment of spontaneous leukemia in germfree or in decontaminated AKR mice.

Prostate Carcinomas in Germfree Rats. MORRIS POLLARD, Lobund Laboratory, University of Notre Dame, Notre Dame, Indiana 46556.—Germfree (GF) Wistar rats live significantly longer than conventional counterparts; and show few of the life-limiting diseases of conventional animals. Early deaths in the latter group have been attributed to pneumonitis, enteritis, and a high incidence of neoplasms, some of which were malignant. Up to age 24 months, GF rats had few benign tumors and no malignant tumors. Older germfree rats developed increasing numbers of benign neoplasms (adenomas) of endocrine and of endocrine-related organs. In GF rats beyond age 36 months, some of their adenomas assumed characteristics of malignancy: increased numbers of mitotic figures, and extensions of tumor cells beyond the normal limits of the organ. Malignant adenocarcinomas

of the prostate gland were found in four-aged GF Wistar rats. In three of them, the tumors had metastasized to other visceral organs; they showed leukemoid reactions, and elevated serum acid phosphatase levels. There is, as yet, no experimental model system for studies on prostatic carcinoma as it occurs in man, which the GF Wistar rat may provide. The GF status assures attainment of this age-related disease. It is conceivable that the development of endocrine tumors reflect an age-related dyshomeostasis. Since viruses have not yet been detected in GF rats, it is likely that the malignant prostate tumors described herein were not associated with viruses.

The Effect of Nicotinamide Adenine Dinucleotide (NAD) and Nicotinamide Adenine Dinucleotide Phosphate (NADP) on the NAD Glycohydrolase-inhibitor Complex of *Pseudomonas putida* KB1

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Abstract

Crude cell extracts of *Pseudomonas putida* KB1 contain a heat-stable NADase (nicotinamide adenine dinucleotide glycohydrolase). Extracts also contain a heat-labile protein inhibitor of the enzyme. Enzyme and inhibitor are present as a complex in cell-free extracts.

The enzyme-inhibitor complex was purified by ammonium sulphate precipitation and chromatography on DEAE-cellulose (diethylaminoethyl-cellulose). Purified preparations were essentially free of unbound inhibitor.

Incubation of purified enzyme-inhibitor complex with NAD (nicotinamide adenine dinucleotide) (1-10 millimolar) leads to NAD hydrolysis. The effect is more pronounced at higher NAD concentrations. Approximately 4 per cent of the total enzyme activity present in the preparations was released by 10 millimolar NAD. This partial activation of the enzyme-inhibitor complex was also observed in the presence of NADP (nicotinamide adenine dinucleotide phosphate).

Introduction

NADases catalyse the reaction:



The enzyme has been isolated and purified from several micro-organisms including *Mycobacterium butyricum* (9), *M. tuberculosis* (5), *Bacillus subtilis* (3), *Neurospora crassa* (3, 8) and *Pseudomonas putida* (16, 17). Some of these NADases are remarkably heat-stable—the *P. putida* enzyme loses only 30% of its activity after 30 min at 100°C. Heat-labile protein inhibitors are often associated with the enzymes in crude cell-free extracts. Enzyme activity is therefore only detected in extracts after inactivation of the inhibitor by heat treatment. The *P. putida* enzyme (23,500 daltons) is combined with a heat labile protein inhibitor (15,000 daltons) in cell extracts. The binding of inhibitor to enzyme is mole/mole. Inhibitor is present in excess over enzyme (16, 17) in cell extracts.

Gholson (4) and others (7, 21) have proposed that NAD(P)ases in both bacterial and mammalian cells are physiologically important in the process of NAD(P) turnover. Nicotinate, formed by deamination of the nicotinamide released from NAD is incorporated into nicotinic acid mononucleotide by nicotinate phosphoribosyltransferase (E.C.2.4.2.11) in the presence of 5-phosphoribosyl-1-pyrophosphate (Fig. 1). NAD can then be resynthesised via the Preiss-Handler path-

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way (19, 20). Pyridine nucleotide turnover in *Escherichia coli* recently has been investigated in detail (12, 13, 15, 18). NAD in this organism appears to be partly recycled by formation of nicotinamide.

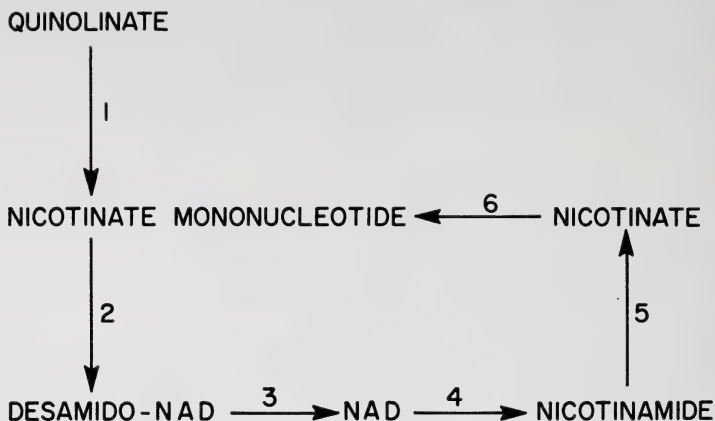


FIGURE 1. The pyridine nucleotide cycle; enzymes of the pathway are: 1) quinolinate phosphoribosyl transferase; 2) adenosine triphosphate: nicotinatemononucleotide adenylyl-transferase; 3) NAD synthetase; 4) NAD glycohydrolase; 5) nicotinamide deamidase; 6) nicotinate phosphoribosyl transferase.

Preliminary results obtained by Griffin (cited by Kaplan) (7) indicate some dissociation of the NADase-inhibitor complex of *Bacillus subtilis* in the presence of 'high concentrations of NAD.' Dissociation of the complex leads to NAD hydrolysis. The exact concentration of NAD used was not stated.

In this present project the NADase-inhibitor complex from *Pseudomonas putida* KB1 has been partially purified and the effect of NAD and NADP on the association of enzyme with inhibitor studied.

Materials and Methods

Growth of the Organism

Pseudomonas putida KB1 (10, 17) was grown on succinate (0.5%, w/v) in minimal media containing (g/l): $(\text{NH}_4)_2\text{SO}_4$, 0.5; KHO_2 , 10.0; nitrilotriacetic acid, 1.0; and trace element solution (1) (1.0 ml/l). The pH of the medium was adjusted to 7.0 with NaOH (10%, w/v).

Culture medium (10 l) was inoculated from two overnight starter cultures (300 ml) and grown at 30°C until the end of the exponential phase. The cells were harvested in a Sorvall continuous centrifuge (12,000 g). Yields of approximately 2.5 g cells, wet weight/l were routinely obtained.

Preparation of Cell-free Extracts

Frozen stored cells were thawed, suspended at 4°C in 0.1 M phosphate buffer, pH 7.0 (prepared as a KH_2PO_4 -KOH mixture) and

broken in 10 ml portions for 5 min, by exposure to the full output of an M.S.E. 100 W ultrasonic generator. The suspension was kept cool by surrounding it with an ice-salt freezing mixture. Cell debris was removed by centrifugation at 0°C (38,000 *g*; 2.0 hours).

Assays

- 1) **Enzyme activity:** Enzyme activity was assayed by the cyanide addition method described by Colowick, Kaplan & Ciotti (2). One unit of enzyme activity is defined as the amount of enzyme which will hydrolyze 1 μ mole NAD/min.
- 2) **Enzyme as enzyme-inhibitor complex:** Enzyme present as enzyme-inhibitor complex was assayed as above after a standard heat treatment (10 min, 100°C) followed by immediate cooling in a crushed ice-salt mixture.
- 3) **Inhibitor activity:** Free inhibitor was assayed by measuring residual enzyme activity after 0.1 ml of test solution had been incubated for 30 min at 25°C with 0.1 ml of a standard enzyme solution (0.05 units).

One unit of inhibitor activity is defined as that amount of inhibitor which will cause 50% inhibition of 1 unit of enzyme after a 30 min preincubation.

- 4) **Protein determination:** Protein was determined by the biuret reaction (6), using bovine serum albumin, fraction V (Sigma, London Ltd.) as protein standard.

Partial Purification of Enzyme-inhibitor Complex

All operations were carried out at 4°C.

- 1) **Fractionation with ammonium sulphate:** Crude cell extract (35 mg protein/ml) prepared as described above was fractionated into eight fractions (% w/v); 0-25, 25-35, 35-45, 45-55, 55-65, 65-75, 75-85 and greater than 85, by the addition of solid ammonium sulphate. After dialysis against 5 l of 0.1 M phosphate buffer, pH 7.0, overnight, each fraction was assayed for enzyme activity after a standard heat treatment (Table 1). Over 80% of the enzyme-inhibitor complex was recoverable between 25-45% saturation. For routine preparations the extracts were fractionated into three portions (% w/v); 0-20, 20-50 and greater than 50 and the 20-50% fraction was retained.
- 2) **Chromatography on DEAE-cellulose:** Preswollen DEAE-cellulose (Whatman DE-52) was equilibrated for 30 min in 0.1 M potassium phosphate buffer, pH 7.0 and packed into a column (35 x 3 cm). After application of the protein sample, the initial buffer solution was passed through the column for one hour before applying a linear gradient (400 ml, total volume) of KCl (0-0.5 M) in 0.1 M phosphate buffer, pH 7.0. Fractions (5.0 ml) were collected with an L.K.B. fraction collector (Ultrarac, type 700) and assayed for enzyme-inhibitor complex and unbound inhibitor. Those fractions containing enzyme-inhibitor complex free of unbound inhibitor were collected and the complex pre-

cipitated with ammonium sulphate (20-50%, w/v). The purified enzyme-inhibitor complex (approximately 25 units purified/column) was redissolved in 0.1 M phosphate buffer, pH 7.0 and dialyzed overnight against the same buffer (5 l).

TABLE 1. *Fractionation of crude cell-extract with ammonium sulphate.*

Fraction (%) saturation	Activity (units)	Activity recovered (%)
0-25	4.6	7.3
25-35	22.0	35.6
35-45	29.5	47.7
45-55	5.0	8.1
55-65	0.8	1.3
65-75	0	0
75-85	0	0
85	0	0

Chemicals

NAD and NADP were obtained from Sigma (London) Ltd. The NAD was Grade III purity.

Results

Purified enzyme-inhibitor complex from *Pseudomonas putida*, prepared as described in Materials and Methods, was incubated with NAD and separately with NADP (1-10 mM). The amount of enzyme bound to inhibitor present in the samples was determined after a standard heat treatment (see Materials and Methods). Enzyme activity, which increased with increasing NAD or NADP concentration, was detected within the range of concentrations tested (Fig. 2). NAD at the lowest concentration (1 mM) was almost completely hydrolyzed during the time of incubation. The enzyme activity in this sample was therefore separately determined from a time course experiment.

As a control experiment enzyme separated from inhibitor by heat treatment was incubated with NAD over a similar range of concentrations. Enzyme was added at the level detected on incubating enzyme-inhibitor complex in the presence of 1 mM NAD. There was an approximately two-fold increase in enzyme activity in the control samples as the substrate concentration was increased from 1.0 to 10.0 mM. This is surprising at these concentrations of NAD, since the K_m of the enzyme is 0.85 mM (17) and the enzyme in purified extracts displays classical Michaelis-Menten kinetics. However, we have previously shown that heat treatment of enzyme-inhibitor complex does not lead to complete removal of inhibitor from the enzyme (17). Fragments of inhibitor appear to remain associated with enzyme until after chromatography on DEAE-cellulose. The increase in enzyme activity in the control samples is therefore probably due to further activation of the enzyme in the presence of substrate.

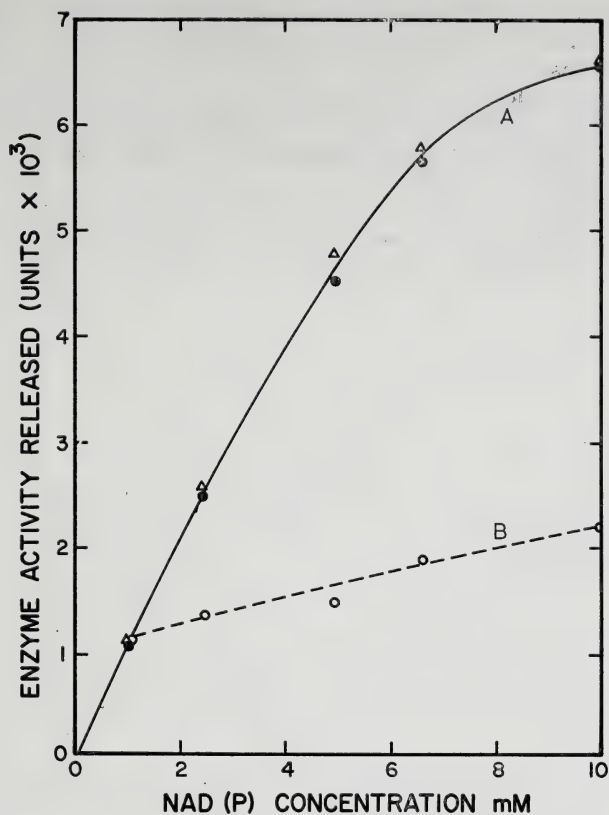


FIGURE 2. Enzyme activity associated with the NADase-inhibitor complex as a function of NAD concentration. Incubation mixtures contained in a final volume of 0.2 ml, either enzyme-inhibitor complex (A) (0.162 units enzyme) or free enzyme (B) (0.0011 units); NAD (O), (0.2 μ mole-2.0 μ mole) or NADP (Δ) (0.2 μ mole-2.0 μ mole) and phosphate (10 μ mole). The temperature was 25°C. Enzyme activity was assayed by the cyanide method (2) after 3.0 hours incubation.

Release of enzyme activity from enzyme-inhibitor complex appears to be rapid since incubation of enzyme-inhibitor complex with NAD (2.5 mM) leads to a linear decrease in substrate concentration over a period of 3.0 hours (Fig. 3). Attainment of equilibrium over a long time period would be expected to lead to departure from linearity.

Discussion

Addition of NAD or NADP to purified NADase-inhibitor complex leads to the release of some enzyme activity. At an NAD concentration of 10 mM this release amounts to 4% of the total amount of enzyme present in solution and bound to inhibitor. Previous work has also shown that the binding of inhibitor to free enzyme is reversibly inhibited by NAD (17). Removal of NAD by dialysis leads to combination of the inhibitor with enzyme. These observations tend to suggest control

mechanisms for maintaining a constant level of NAD in the cell. If enzyme and inhibitor are physically separated within the cell, high concentrations of NAD will reduce the possibility of enzyme-inhibitor interaction and lead to a lowering in the level of NAD. This present study indicates that preformed enzyme-inhibitor complex can be partially activated by high NAD concentrations, again leading to lowered pyridine nucleotide levels.

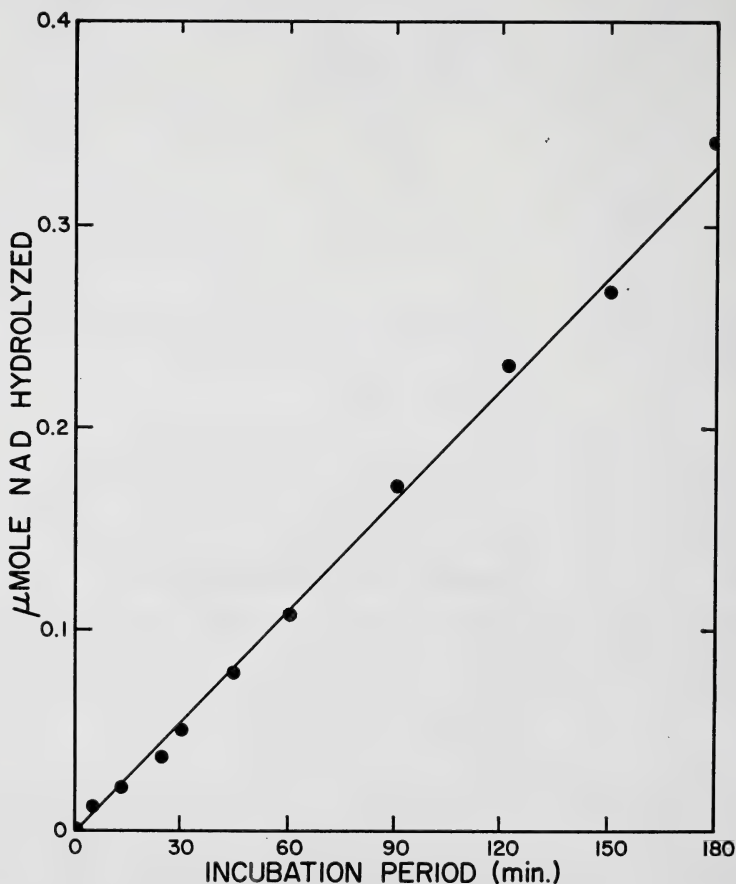


FIGURE 3. Time course of enzyme-inhibitor complex activation. Incubation mixtures contained in a final volume of 0.2 ml; enzyme-inhibitor complex, NAD (0.5 μ mole) and phosphate buffer pH 7.0 (10 μ mole). The solutions were incubated for the times indicated in the figure at 25° C, and the enzyme activity assayed by the cyanide addition method (2).

For an enzyme to function under physiological conditions the K_m should be of the same order as the concentration of its substrate *in vivo*. Calculation from values reported by London & Knight (11) and Luria (14) indicates that the intracellular NAD concentration in *Pseudomonas putida* KB1 is approximately 0.7 mM. This is of the same order as the

value (1.3 mM) reported for certain nicotinate auxotrophs of *Escherichia coli* (12). These values are close to the K_m of the NADase (0.85 mM) (17) in *P. putida*.

Pyridine nucleotide turnover in *E. coli* is thought to involve at least two cycles, the cycle ascribed to Gholson (4) (Fig. 1) and a second pathway which involves nicotinamide mononucleotide as an intermediate, possibly formed by NAD dependent DNA-ligase (15). Turnover studies have not been undertaken with *P. putida* although the presence of an NADase-inhibitor system in the organism which is partly influenced by NAD levels suggests that at least the first pathway may be present in this organism.

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Extracellular Pectic Enzymes Produced by *Colletotrichum graminicola*¹

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Abstract

Activities for endo- and exo-polygalacturonase, endo-polymethylgalacturonase and two endo-pectin methyl-trans-eliminases were identified in culture filtrates of *Colletotrichum graminicola*. Extracts of infected maize pith tissue, both susceptible and resistant to *C. graminicola*, exhibited qualitatively identical patterns of enzyme activity. However, activity was markedly less in extracts prepared from infected, resistant maize pith than in extracts from infected susceptible pith.

Synthesis of this broad spectrum of pectic enzymes is suggested to be a significant factor in the successful parasitism of corn by *C. graminicola*.

Introduction

Anthrachnose of corn, caused by *Colletotrichum graminicola* (Ces.) Wils. has been considered of little importance in the United States; but in Europe and India the fungus causes substantial crop losses (4). Recently, a severe case of anthracnose caused complete crop failure in commercial sweet corn plantings at three different locations in Benton County, Indiana (13). The extreme pathogenicity of *C. graminicola* to various sweet and dent corn hybrids and inbreds could result in maize anthracnose becoming economically important throughout Indiana and the United States.

Although *C. graminicola* can infect all parts of the plant, the stalk rot phase is probably most important because infection may occur early in the growth of the host. The stalk becomes soft and the whole plant collapses, usually breaking at one or more internodes above the ground (9). Thus, stalk rot alone could cause rapid and extensive crop loss at any time in the growing season.

Pectic substances, which form a portion of the plant cell wall and serve as cementing substances between cells, are known to be degraded by extracellular hydrolytic and trans-eliminative enzymes produced by numerous phytopathogenic fungi and bacteria (2, 14). In addition, the degree of an organism's pathogenicity may at least be partly dependent on the type of extracellular enzymes produced (12).

Because of the importance of the stalk rot phase of corn anthracnose, this study was undertaken to determine the ability of *C. graminicola* to produce extracellular pectolytic enzymes.

Methods and Materials

Culture of the Fungus

Stock cultures of *C. graminicola* (isolate 104) were maintained on oatmeal agar (11) under a constant light source of 300 foot candles at

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24° C. Liquid cultures were grown for 14 days in shake culture followed by 7 days still culture. The medium contained one per cent pectin as the sole carbon source and included the following salts per liter: 5.0 g NH_4NO_3 , 0.5 g MgSO_4 , 0.01 g ZnSO_4 , 0.015 g FeCl_3 and 2.5 g KH_2PO_4 . A check for contamination was made by inoculating plates of oatmeal agar, beef peptone agar, and potato dextrose agar (11) with samples from each culture flask.

Host Tissues

One sweet corn hybrid, Jubilee, and two dent corn inbreds, 33-16 and H-59 (susceptible, resistant and susceptible respective to *C. graminicola*) were used as host tissue. Plants, grown in the greenhouse for 5 weeks, were cut at the soil line and living pith tissue was aseptically removed from the first and second extended internodes. The tissue (30 g) was cut to 3-inch lengths, split longitudinally and placed with the cut surface facing up in sterile petri dishes lined with moistened filter paper. The exposed pith was inoculated and incubated in the dark at 24° C for 60 hours. Control uninoculated tissue was similarly treated with 0.5 ml sterile distilled water.

Culture Filtrate and Tissue Extract Preparations

Extracts from liquid cultures were prepared by filtering the culture liquor through cheesecloth, centrifuging (15,000 rpm at 4° C), filtering through a Millipore Filter (0.2 μ) and dialyzing the filtrate at 4° C for 12 hours. Toluene (1 ml/l) was used to inhibit bacterial growth. Inoculated pith tissue was homogenized in an equal volume of 0.25 M NaCl. The homogenate was treated as described above. Uninoculated pith tissue treated in the same manner served as a control. Preparations were frozen (—20° C) until used for enzyme assays.

Enzyme Assays

Exo-polygalacturonase (exo-PG) was measured by the reducing group method of Somogyi (10) using Nelson's arsenomolybdate (8) as the color reagent. One per cent (w/v) sodium polypectate in 0.1 M sodium acetate-acetic acid buffer (pH 3.6, 4.0, 4.5, 5.0) served as substrate. Reaction mixtures consisted of 9.5 ml substrate and 0.5 ml culture filtrate. The mixtures were incubated at 30° C and 1 ml samples were removed at 0, 15, 30, 45, and 60 min. Endo-polygalacturonase (endo-PG), endo-polymethylgalacturonase (endo-PMG) and endo-pectin methyl-trans-eliminase (endo-PMTE) were measured by viscosity reduction (1, 3, 6) in Ostwald-Cannon-Fenske No. 300 viscosimeters at 30° C. Activity was expressed as the reciprocal of the time in minutes required for one-half viscosity reduction multiplied by 1,000. Reaction mixtures consisted of 3 ml 1.2% sodium polypectate or pectin, 2 ml water or 0.25 M CaCl_2 , and 1 ml enzyme preparation. Substrates were buffered with 0.05 M tris-HCl (above pH 7) and 0.05 M citric acid—NaOH (below pH 7).

Pectin methyl-trans-eliminase was also determined by the direct spectrophotometric method of Mullen and Bateman (7) by measuring

change in absorption at 230 nm of reaction mixtures consisting of 1 ml 0.1% pectin, 1.8 ml 0.025 M CaCl_2 and 0.2 ml filtrate preparation. All assays were carried out in triplicate and autoclaved enzyme preparations served as controls.

Results

Viscosity reduction of sodium polypectate and pectin indicated the presence of extracellular pectic enzymes in culture filtrates of *C. graminicola*.

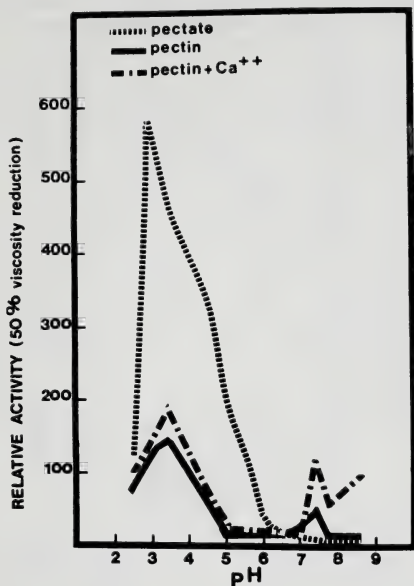


FIGURE 1. Effect of pH on viscosity reduction of sodium polypectate, pectin and pectin plus calcium by the culture filtrate of *Colletotrichum graminicola*.

A single peak for viscosity reduction of sodium polypectate was observed within the pH range studied (pH 2.5-8.6) suggesting the presence of an endo-PG with a pH optimum of about 3.0 (Fig. 1). A slight distortion of the viscosity reduction curve between pH 4 and 5 suggested the presence of a second enzyme capable of degrading sodium polypectate. That this enzyme is probably an exo-PG is suggested by the rapid liberation of reducing groups from sodium polypectate by a component of the filtrate with a pH optimum at 4.5 (Fig. 2).

Viscosity reduction of pectin occurred at pH 3.5 and pH 7.4 (Fig. 1). Addition of calcium to reaction mixtures caused a slight increase in activity at pH 3.5. However, activity at pH 7.4 was more than doubled suggesting the presence of a calcium stimulated pectin methyl-transeliminase in the alkaline range. A second calcium activated transeliminase is suggested by the increase in activity observed above pH 7.8. Absorption of reaction mixtures at 230 nm (2, 5, 7) further confirms the presence of trans-eliminase activity (Fig. 3). Maximal

absorbency change occurred at pH 8.6 whereas only a slight increase was observed between pH 7.3 and 8.2. Comparison of change in absorption and viscosity reduction data suggests that culture filtrates contained an endo-PMTE, pH optimum near 7.4, and an exo-PMTE, pH optimum near 8.6. Trans-eliminative degradation of pectin could not be detected below pH 7.0 suggesting the observed viscosity reduction in the acid range was the result of hydrolytic cleavage of α 1, 4-glycosidic bonds of pectin by an endo-PMG with a pH optimum near 3.5.

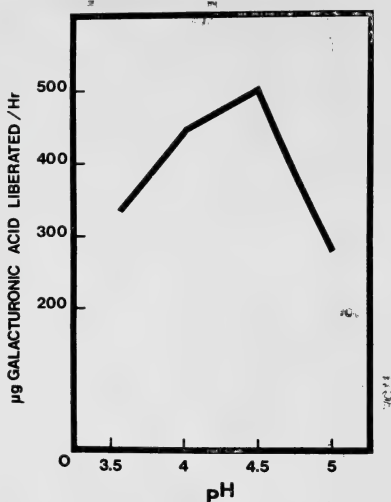


FIGURE 2. Effect of pH on the liberation of reducing groups (galacturonic acid equivalents) from sodium polypectate by the culture filtrate of *Colletotrichum graminicola*.

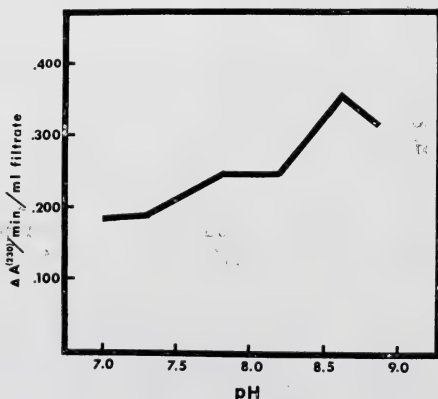


FIGURE 3. Effect of pH on trans-eliminative degradation of pectin by the culture filtrate of *Colletotrichum graminicola*. Data expressed as change in absorbance at 230 nm/min./ml filtrate.

Tissue homogenates from infected, susceptible maize pith exhibited qualitatively identical patterns of enzyme activity to those found in culture filtrates. Endo-PG was the predominant enzyme in both tissue and culture filtrate preparations.

Maize lines exhibiting differential resistance and susceptibility to *C. graminicola* (based on leaf inoculations) appeared equally susceptible to pith maceration 60 hours after inoculation with the fungus. However, activity of endo-PG, endo-PMG and endo-PMTE was significantly less in enzyme preparations from the resistant maize than in preparations from susceptible maize lines (Table 1).

TABLE 1. Viscosity reduction of pectin and sodium polycetate by extracts of *Colletotrichum graminicola* infected resistant and susceptible maize pith tissue.¹

Maize Host	Pectin		Sodium Polycetate pH 3.0
	pH 3.5	pH 7.4	
H59 (s) ²	153.8 ³	47.6	500
Jubilee (s)	135.1	58.8	400
33-16 (r)	47.6	16.1	34.5

¹ Reaction mixtures consisted of 3 ml 1.2% buffered substrate, 2 ml water and 1 ml tissue extract.

² (s), susceptible; (r), resistant to *C. graminicola*.

³ Data represents the average of three replications and is expressed as the reciprocal of time in minutes required for 50% viscosity loss of the substrate multiplied by 1,000.

Discussion

At least five pectic enzymes were synthesized by *C. graminicola* when the fungus was grown in liquid culture with pectin as the sole carbon source. They included exo- and endo-polygalacturonase and an endo-polymethylgalacturonase which degraded pectic acid and pectin, respectively, by hydrolytic cleavage. In addition, exo- and endo-pectin methyl-trans-eliminases were present. Both are calcium stimulated and specific for pectin as a substrate. Qualitatively identical patterns of enzyme activity were observed in homogenates of infected pith of susceptible maize.

Although pectic enzyme synthesis by plant pathogenic fungi is not uncommon (2, 14), the synthesis of a majority of the known pectic enzymes by *C. graminicola*, both *in vitro* and *in vivo*, suggests that these enzymes play a significant role in the ability of the fungus to cause stalk rot of living maize pith.

In addition, it is important to note that although enzyme activity from infected pith tissue of resistant maize was lower than that observed from infected susceptible maize, both tissues were completely macerated within 60 hours of inoculation. This apparent lack of expected resistance could be the result of the combined effect of the broad spectrum of pectic enzymes produced by the fungus. These data suggest that pith resistance in addition to leaf resistance should be used as criteria for breeding resistance to maize anthracnose.

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The Therapeutic Promise of Molecular Biology¹

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Abstract

The search for ideal therapeutic agents has been in progress since primitive man discovered that certain trees, plants and shrubs had varying effects upon him after ingestion. The most intensive efforts have been concentrated during the past 30 years and the rewards of such efforts have been great. However, success appears to have met with the law of diminishing returns as novel drugs have become increasingly rare. Fortunately, advances in basic biological research provide new areas of exploitation. An adventure in one of these, molecular biology, which has led to the development of a novel inhibitor of reverse transcriptase, is described.

Introduction

The eternal search for ideal therapeutic agents has come a long way since that day when God, according to ancient legend, used powdered root from the European mandrake plant to anaesthetize Adam while He removed the rib which became Eve and thus created the first drug related problem.

A variety of drugs have been discovered during the following centuries as we progressed from single empirical observations that create folk remedies to the point where highly skilled teams of scientists produce drugs that stimulate, tranquilize, calm, expand, constrict, destroy to the tune of 782 million prescriptions each year, a 5 billion dollar industry. The history of the United States Pharmacopoeia (USP) provides an excellent example of the progress made in the past 150 years. The prototype of this compendium appeared in 1820. In USP I, published in 1830, 70% of the drugs listed were of vegetative origin; in USP X (1924), 30%; in USP XVII (1964), 10%. Natural drugs that predate the USP, but remain with us even today, include opium, rauwolfia, belladonna, digitalis, strychnine, emetine and curare. The cumulative number of organic chemicals included since its inception exceeds 300—from morphine and quinine in USP I to griseofulvin and cyclophosphamide in USP XVII (9).

But there is trouble in paradise. Despite all-out effort, useful results in terms of new drugs are rarer and rarer. It takes an average of 11.25 years to develop a functional drug from the inception of chemical research to approval for marketing (4). Inherent high costs of research and shrinking profits on old products make it imperative that new approaches be tried in the art and science of new drug development if our best efforts are to lead to clinically useful drugs. The scope

¹ This is an overview. The experimental details are due to both the theoretical and experimental abilities of members of the Molecular Biology Department, in particular Dr. J. Colbourn for enzyme chemistry; Dr. R. Erickson for biological approach and relevant data; and Dr. M. Kotick for the theoretical and experimental aspects of the organic chemistry.

of therapeutic research has been extended beyond those disciplines of science which are traditionally regarded as belonging to medicine. The evolutionary process has resulted in widening the range of talents which now contribute to the advancement of medical knowledge and which progressively adds tools for its practice. We think the time is right to commit *our* talents and resources to new directions.

Molecular biology focuses on the structure, function and biosynthesis of the macromolecules that initiate, sustain and maintain living organisms. Since breakdowns in such vital cellular functions are what we recognize as disease, an understanding of life processes in terms of molecular phenomena should bring us a new generation of therapeutic agents. Molecular biology's most important component, the structure and function of nucleic acids, is a major concern of my department.

Specifically, our nucleic acid research program is concerned with 1) viruses and 2) neoplastic disease and the means by which these disease states may be controlled or, more hopefully, cured. Success in the treatment of either syndrome has been disappointing. Effective antiviral agents have not appeared at the same pace as was the case with antibacterial agents. Drug toxicity continues to complicate cancer therapy.

Virology

Exposure of a cell to viral stress may result in: 1) the induction of enzymes required for viral growth; 2) the induction of enzymes required for the protection of the cell; 3) integration of the viral genome into the cellular genome; 4) the production of substances which interfere with the normal regulatory mechanisms—cell surface changes included; 5) production of substances which result in the destruction of the cell; 6) production and/or release of substances which are harmful to other cells—histamine, serotonin and other mediators; and 7) production and/or release of substances which inhibit normal response—such as immunosuppression by murine leukemic viruses.

For the selective inhibition of viruses we must somehow block a step unique to the viral replicative cycle in a cell supporting a myriad of other metabolic events. General metabolic inhibitors, such as Actinomycin D which interferes with the formation of DNA directed RNA, not only affect DNA viruses but the cell processes as well. On the other hand, iododeoxyuridine, which inhibits thymidine kinase, is effective in herpes conjunctivitis since the virus multiplies, but the cell does not.

So where does one start? We do know that the viral life cycle permits us to choose from several possible steps a target for viral inhibition. 1) Direct extracellular destruction of virions—immunization is a common way of achieving viral inactivation outside of the cell. Its usefulness is limited to certain viruses, however, by the prophylactic character and antigenic specificity of the immune response. 2) Prevention of viral absorption and penetration into the cell—Amantadine is the only known agent which effectively blocks the absorption-penetration

step. 3) Inhibition of viral replication within the cell may be blocked at any one of several stages: viral uncoating; replication of the viral genome; viral protein synthesis; assembly of new virions. Several agents are available which are known to inhibit the various steps. Guanidine and 2a hydroxybenzyl benzimidazole inhibit replication of the viral genome, but viruses mutate to dependence. Isatin β -thiosemicarbazone inhibits late viral mRNA so that no late protein and no mature particles are formed—only defective ones. Iododeoxyuridine, fluorodeoxyuridine and bromodeoxyuridine inhibit thymidine kinase and sometimes cause the synthesis of empty viral particles, but natural resistance develops. Arabinosyl cytosine inhibits reduction of cytidylic acid to deoxycytidylic acid. The most potent inhibitor is interferon. Interferon inhibits viral replication by blockade of the synthesis of viral protein (translation). However, some evidence is available which suggests an effect at the transcriptional level (inhibits mRNA synthesis). Poly I:C is an effective inducer of interferon. 4) The release of mature viral particles from the host cell may be prevented by rifamycin.

The discovery of a nucleic acid polymerase which is capable of reversing the usual flow of genetic information has added a new dimension to the problems of chemotherapy. While this enzyme has been found in RNA tumor viruses, its role is not yet completely understood. However, the presence of a template specific DNA polymerase in all oncornaviruses and its general absence in non-oncogenic RNA viruses suggests a specific role of this enzyme in carcinogenesis by RNA tumor viruses.

There are three important differences in the life cycle of viruses containing this enzyme. Such viruses are non-lytic and tend to have long lasting eclipse or latent phases. More important is that they produce new DNA which leads to some real problems.

The new DNA formed by this reaction may: 1) remain as free dormant intracellular (intranuclear) DNA; or 2) replicate with or independently of cell mitosis; or 3) transcribe into products serving to complete new virion production; or 4) transcribe into products expressing information that converts normal cells into cancerous ones (1).

All of these possibilities have potentially significant biological implications in viral life cycles, gene amplification, embryo differentiation, response to antigens, gene transplantation, and, of course, cancer etiology.

Cancer apparently results from the inability of the cell to turn off its replicative processes; its pleiotypic control coordinator is asleep at the switch. The coordinator either 1) does not receive the signal; or 2) receives a distorted signal; or 3) does not perceive the signal; or 4) does not respond to the signal; or 5) responds inappropriately; or 6) any or all combinations.

Our concern, for the purposes of this paper, is limited to those forms of cancer that involve viral agents, *i.e.*, the signal is modulated by some virus or another.

Polynucleotide Chemistry

The key role played by nucleic acids in both viral and neoplastic disease suggests that synthetic analogs of nucleic acids and polynucleotides may be used to influence the course of these processes. We do know polynucleotides have several definite actions on biological systems. They 1) induce interferon; 2) have an adjuvant effect upon the immune response; 3) antitumor activity; 4) inhibitory effects upon enzymes; and 5) are involved in the release of chromatin restrictions for DNA synthesis.

Synthetic polynucleotides differ from the naturally occurring nucleic acids in that their compositions are dictated and specified by the components used in their preparation and by the particular techniques employed for their enzymatic preparation. Ribopolynucleotides are formed by the action of polynucleotide phosphorylases from bacterial sources on ribonucleoside 5'-diphosphates. Polydeoxyribonucleotides are most commonly prepared with deoxynucleotidyl terminal transferase in a primer dependent reaction using deoxyribonucleoside triphosphates as substrates.

An infinite number of polynucleotides could be prepared if a relatively new approach termed "fragment coupling" proves successful (7). This method involves the condensation of suitably protected, preformed oligonucleotide blocks, having 5' phosphomonoester end groups, in such a manner that the chain length should be approximately doubled at each condensation step. It is quite obvious what variety might be expected from such methodology.

To date, most of the synthetic polynucleotides have been derived from substitutions or replacements in the heterocyclic portion of the nucleotide. Modifications of this type have mainly been limited to n-alkylated compounds and several 5-substituted pyrimidine nucleosides. Substitutions of these functions for the oxygens of the pyrimidine base or phosphate groups have been reported to give compounds which show unusual physical properties and interesting biological activity. The preparation of purine and pyrimidine containing polymers on a metabolically stable polymethylene backbone has received much attention (8).

Until recently, the only sugar modified polynucleotides prepared were those containing 2'-O-methoxy substituted ribonucleosides. An area which appeared appropriate for investigation was alteration, substitution and replacement of various functional groups in the carbohydrate moiety of nucleosides. Modifications of the sugar component appear to alter the pucker of the furanose nucleoside ring which results in subtle changes in the conformation of the polynucleotide. The relationship between pucker and biological activity is not understood but differences in pucker of this type may be related to the basic differences between the structure and functions of DNA as compared to RNA.

Consideration of the structures of a typical homopolynucleotide indicates that a number of features must be retained for recognition of the polymer as a polynucleotide. A phosphate substituted moiety in a position approximating the 5'-hydroxy methyl group must be present as well as an 'acceptor' for formation of a phospho-diester bond.

The C-N bond is not necessary for the enzymatic polymerization of a nucleotide phosphate. For example, the purine nucleoside antibiotic, formycin, in which the C₈ and N₉ are interchanged, has been polymerized and the polymer found to exhibit many unusual properties. The art of synthetic nucleoside chemistry has only recently advanced to the stage where C-glycosyl compounds have become available. Many developments in this area are expected shortly; the compounds resulting from this work will be applicable to the preparation of nucleosides for use in polynucleotide synthesis.

The twist about the C-N bond—*anti* and *syn* denote the two stereochemically preferred ranges in the orientation of the heterocyclic base portion of nucleosides about the covalent nucleosidic bond linking the base to the sugar moiety. Although there may be a considerable energy barrier between the *syn* and *anti* ranges, the conformational energies between these states may not differ greatly. Several workers have suggested that the conformation about the nucleosidic bond is correlated with the pucker of the sugar ring.

Most nucleosides crystallize in the *anti* conformation and this is also the conformation observed in the DNA double helix and other multistranded polynucleotide complexes. Hydrogen bonding of the Watson-Crick type is dependent on the heterocyclic base portion being in the *anti* conformation. It has recently been observed that purine nucleosides substituted with a bulky group in the 8-position crystallize in the *syn* conformation. The triphosphates of these nucleoside analogs cannot be polymerized by the Q β replicase or *E. coli* transcriptase enzymes. Evidently, the altered stereochemistry of these 8-substituted nucleoside triphosphates makes polymerization difficult (presuming that polymerization requires substrates being in the *syn* conformation).

Formycin, the purine nucleoside antibiotic previously mentioned, has also been shown to exist in the *syn* conformation in the crystal state. Evidence indicates that this nucleoside analog also exists in the *syn* conformation in the homopolymeric state whereas the situation may be reversed in heteropolymers as well as in double stranded complexes.

The configuration at the C-1'-carbon atom of the sugar may also be modified. Only nucleosides with the β - configuration at C 1' of the sugar have been polymerized. Will the enzymes which carry out the polymerization of nucleotides be able to polymerize the α - anomers?

The synthesis of cytosine and uracil nucleosides under potentially prebiotic conditions has been studied by L. E. Orgel and co-workers at the Salk Institute (3). An unusual point has arisen from this work; *viz.*, that the reaction of *D*-ribose with prebiotic precursors, such as cyanamide, cyanoacetylene, gave α -*D*-ribofuranosylpyrimidines whereas reaction of *D*-arabinose gave arabinosyl nucleosides. It was further demonstrated that irradiation of aqueous solutions of the above nucleosides resulted in anomerization and epimerization. Studies on the chemistry of prebiotic nucleoside synthesis have yielded an efficient synthesis of the antitumor agent, arabinosyleytosine.

Why do all the nucleic acids investigated to date contain only β -*D*-nucleosides when an efficient method exists for the synthesis of

α -*D*-nucleosides under primitive earth conditions? Since most enzymes are known to exhibit rigid substrate stereospecificity, we are faced with the problem of which came first: β -*D*-nucleoside phosphates or an enzyme capable of polymerizing only nucleosides of the β -configuration. Also, the α -anomer of 6-thioguanine deoxyriboside is a compound of current interest in experimental tumor therapy. The proposed mechanism of action of this compound is by incorporation into nucleic acids.

A logical extension of this work is the preparation of C 1'- α -purine nucleosides whose activation and polymerization would be studied. Double stranded complexes of these α -nucleoside purine-pyrimidine pairs might possess unusual stability with regard to polynucleotide degrading enzymes.

Turning now to C 2' of the carbohydrate moiety of polynucleotides, the major difference between DNA and RNA resides at this position. DNA has a hydrogen at C 2' whereas RNA has a hydroxy group in the ribo- or down-configuration.

The role of the 2'-hydroxyl group in polynucleotide structure is an intriguing question. The methylation of the 2'-hydroxy groups in poly rA results in an increase in the thermal stability of the double stranded, acid structure of poly rA, while no significant effect on the single stranded conformation is observed. Methylation of the 2'-hydroxyl groups had virtually no effect on the thermal stability of the double stranded 2'-*O*-methyl-poly rA:poly rU complex. This result indicated that the presence of an unsubstituted 2'-hydroxyl group in poly rA is not essential for the stabilization of the double stranded conformations of poly rA. The polymerization of 2'-*O*-methylcytidine-5'-diphosphate has been reported (6). The polymer, as might be anticipated, has increased stability to ribonucleases which hydrolyze ribonucleotide linkages *via* 2', 3'-cyclic phosphate intermediates. Studies on these polynucleotide analogs indicated that the involvement of the ribose 2'-OH as a hydrogen bond donor in an intramolecular hydrogen bond need not be considered in the formation of either single stranded stacked structures, or the twin-helical forms. However, the replacement of the 2'-OH in poly rU by 2'-*O*-methyl leads to a pronounced stabilizing effect on complexes with poly rA or poly dA. These results again reflect the view that hydrogen bonding is not important in the stability of poly-2'-*O*-methyl rA or poly-2'-*O*-methyl rC. It appears that the source of the observed stability effect is related to modifications in the conformation of the carbohydrate moieties of the polynucleotides.

To date, one of the more interesting series of unusual polynucleotides prepared in our laboratory is the series of 2'-halogeno-2'-deoxy-polyuridylic and -cytidylic acids (5). In these polymers, the 2'-hydroxyl group of polyuridylic or cytidylic acids has been replaced by either a fluorine or chlorine atom in the down position at C 2'. While these polymers possess many unusual properties, such as resistance to the action of several polynucleotide degrading enzymes, the double stranded complex with the complementary purine polynucleotide has been shown not to induce interferon.

The chemistry of the penultimate position of the carbohydrate moiety of nucleosides—C 4' -, and most carbohydrates in general, has been relatively little studied with regard to chemical modification. The synthesis of *L*-adenosine represents the first attempt to prepare ribonucleosides for biological and physical investigation of enantiomorphic nucleic acid components. Work in the deoxyribonucleoside series, represented by the preparation of 2'-deoxy α - and β -*L*-adenosines and -guanosines and *L*-isomers into RNA- or DNA-like fragments, would provide exciting information concerning helical structures and properties of nucleic acids. The finding that α -*L*-adenosine acts as a substrate for adenosine deaminase suggests the potential biological activity of stereoisomers of nucleosides, a possibility borne out in the case of the selectively toxic nucleoside, 2'-deoxy- α -thioguanosine.

The effect of the sugar ring oxygen on the ability of a nucleotide analog to be polymerized is as yet unknown. In the single stranded random coil form of polyribouridylic acid, as well as in the twin stranded helical form, the conformation is such that the 2'-OH of the uridine residues hydrogen bond to the ring oxygen of a neighboring nucleotide residue. Light could be shed on this point by the preparation of compounds wherein the ring oxygen is substituted by sulfur, nitrogen or methylene. Compounds of this type are known in nature—the nucleoside antibiotic aristeromycin differs from adenosine only in the replacement of the carbohydrate-ether oxygen by a methylene group.

Inhibition of Reverse Transcriptase by Polynucleotides in a Cell-Free System

Starting with the observation that poly uridylic acid (poly U) inhibits the DNA polymerase of Rauscher murine leukemia virus, we set out to determine whether alterations in the structure of that polynucleotide could influence inhibitory activity, specificity of inhibition, and *in vivo* drug potential. Our initial approach to the problem was two-fold. First, to acquire as many analogs of poly U as possible and given the appropriate test system, begin to gather clues as to what alterations affected activity. Second, to study the mechanism of inhibition in detail and to use the data obtained to design new polymers.

The cell-free test system was of obvious critical importance. Since we were approaching this problem from its molecular aspect, a well defined system was required. The following was used.

Avian myeloblastosis virus (AMV) is purified by differential and zonal ultracentrifugation, disrupted with non-ionic detergents and the DNA polymerase is isolated by column chromatography. The system measures the incorporation of thymidine triphosphate into poly dT. The template for the polymerization reaction is dT₁₀:poly A and the reaction takes place in a defined buffered salt solution.

Our results concerning the mechanism of inhibition were reported in detail (2, 5) and have provided us with many clues as regard future polymer design. Briefly summarized, we found: 1) kinetics of inhibition show poly U interacts directly with the enzyme in addition to obvious

template interactions; 2) inhibition by poly U is competitive; 3) the inhibition is independent of the nature of the divalent cation; 4) the inhibition is not influenced by actinomycin D; 5) the polymer must be single stranded; 6) the inhibitory polymer must have a chain length greater than 200 residues/molecule; 7) inhibitory activity is abolished by the presence of RNase; and 8) poly U does not interfere with the RNase H activity that co-purifies with the polymerase.

What do these results tell us? First, poly U is a competitive inhibitor of the template binding site on the viral DNA polymerase. Hence, we are approaching viral chemotherapy from a novel aspect. Most other chemotherapeutic agents attack this enzyme reaction from the substrate binding site since their design rationale is based on altered, toxic DNA (or RNA) precursors. Our approach offers a greater opportunity for specificity of inhibition as template binding sites must be specific to insure genome replication while most viruses utilize substrates identical to those of the host. In addition, they may be non-toxic to the host organism.

Second, these results suggest the structure of a good enzyme inhibitor. It must be single stranded and larger than 200 residues/molecule. The studies also tell us that a nuclease resistant polymer *may* be a better *drug* than poly U since by adding a contaminant (RNase) to our defined system we can destroy our inhibitor.

The initial screen of available polymers revealed that both the base and sugar were important for activity. Substitutions at the 4- and 5- positions of the ring significantly altered activity. Poly(2-oxy-4-aminopyrimidine) is an active template but an inactive inhibitor while poly (2,4-deoxypyrimidine) exhibits just the opposite activity. Making the compound resistant to RNase (*e.g.*, poly U—poly dU) decreased activity. Addition of a bromo or methyl group in the 5- position increased inhibition. Most significantly, substitution of the 2'-hydroxyl function by halogeno groups (*e.g.*, poly dUfl, poly dUcl and poly dCcl) greatly

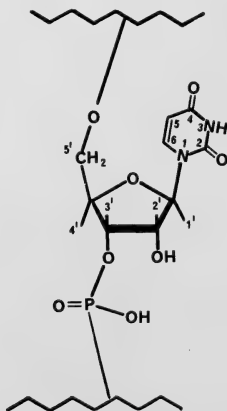


FIGURE 1. Fluorine is substituted for the 2'-hydroxyl group in poly 2'-fluoro-2' deoxyuridylic acid (poly dUfl).

enhanced activity (Fig. 1). These compounds are nuclease resistant and have been chosen for *in vitro* and *in vivo* test compounds to establish model systems. We have established the specificity of poly dUfl (Table 1) and all our polymers will be checked in this manner.

Other leads, provided by this structure activity relationship, are also being pursued. We know base-pairing can destroy activity and poly A exists in most eucaryotic cells. We predict that an analog of poly dUfl that cannot base-pair would be a better antiviral agent. This prediction is now being tested. Other areas include charge distribution of the polymer and the possibility of designing polymers possessing functions that could destroy the active site on the enzyme.

TABLE 1. Effects of poly 2' fluoro-2' deoxyuridylic acid (poly dUfl) on selected nucleic acid polymerases.

Inhibition	No Inhibition
RNA-dependent DNA Polymerases	DNA Polymerases
Avian Myeloblastosis Virus	Escherichia coli
Rous Sarcoma Virus	Micrococcus luteus
Feline Leukemia Virus	Calf thymus
Murine Sarcoma Virus	Normal Human Cell
Mason-Pfizer Monkey Virus	(Polymerase II)
Wooley Monkey Virus	
RNA-dependent RNA Polymerase	
Vesicular Stomatitis Virus	
DNA-dependent RNA Polymerases	
Escherichia coli	
Micrococcus luteus	
DNA Polymerase I	
Normal Human Cell	

Antiviral and Antitumor Activity

The logical extension of these studies involves testing for *in vitro* and *in vivo* inhibition of both viral replication and viral activity expressed as cell transformation and tumor development. To date, our test systems have not been satisfactory. While considerable information has been acquired concerning cell-polymer interactions, no definitive data on inhibition has been obtained.

In vitro assay methods that depend upon the measurement of new progeny are prone to error when the synthetic step to be inhibited occurs early in the replicative process. Viruses whose synthesis has proceeded past that point will develop into mature virus particles. On the other hand, a compound may inhibit cellular processes and give the impression of specific antiviral activity.

Problems also arise when attempts are made to assay inhibitors of viral induced transformation by focus assay. In transformed cells, the property of contact inhibition is diminished so that when such cells are plated in solid medium discrete colonies (foci) of piled up cells appear. If normal cells are plated with a transforming virus, transformation is determined by the appearance of foci on the plates. A compound

interfering with transformation would diminish or eliminate foci as compared to a control plate without inhibitor.

In this specific case, we have had considerable variability in our results. We have traced the problem to the extreme sensitivity of our host cells, chick embryo fibroblast, to environmental manipulation. We have switched to UCI-B cells, a line derived from Balb/313 cells, that transform in response to a murine leukemia virus. An established cell line may provide more consistent results than primary cell cultures.

The *in vivo* inhibition of virus replication is now being tested in what we believe is the best animal-model system available, the AKR mouse-Gross mouse leukemia virus (MLV) interaction. These mice carry the virus in a latent form and at an age of approximately 8 months develop leukemic disease. This system is advantageous in that it not only allows the testing of cytotoxic drugs used in cancer chemotherapy (*e.g.*, methotrexate, 5-fluoro-uracil, cyclophosphamide, chlorambucil, etc.) but also combined chemotherapy (*e.g.*, a cytotoxic agent in combination with a drug to prolong the state of remission).

Our initial tests have been designed to assess the ability of poly dUfl to affect the maintenance of remission. We have chosen this course of investigation since many cytotoxic drugs are available to induce the initial state of remission, but few drugs can prolong this state which lasts approximately 6 weeks in the AKR mouse.

Poly dUfl is non-toxic to conventional mice at levels up to 20 mg/kg administered 3 times/week for 3 weeks. Histological sections were prepared from spleen, thymus, lymph node, Peyers patch, lung, kidney, adrenal and pancreas. The only prominent abnormalities were enlarged germinal centers in the spleen, lymph node and Peyers patch.

Since we plan to use cyclophosphamide to induce remission, these tests will have to be carried out under germ-free conditions as this compound destroys the animals' immunological defense mechanisms.

We have initiated studies with a small number of AKR mice in germ-free conditions to "iron out any wrinkles" that could develop in the system. At present ($\approx$ 6 months of age), one mouse has developed what appeared to be a large lymphoid tumor of the thymus, showed a high WBC count and was placed on cyclophosphamide (100 mg/kg) for 8 consecutive days. This animal is now on poly dUfl treatment. Other mice have received 3 injections of poly dUfl. We have 105 young AKR mice (2-3 months of age) bred and raised under germ-free conditions in our laboratories which will be utilized in a more statistically significant test.

One of the unexpected bits of information obtained from these studies is that poly dUfl is a potent immunological adjuvant when administered intravenously to mice. This work was initiated by the late Dr. W. Braun and is now being conducted by Dr. O. Plescia at Rutgers University. These data were unexpected because it had been thought that poly A*poly U was a good adjuvant because its double stranded nature protected the poly A and delivered this component to

the cell's active site. Poly dUfl is single stranded. This is a very important aspect of the central problem and is to be pursued "in-house" by the immunology research group of our department. The effects noted in the toxicity experiment—enlarged germinal centers in the spleen, lymph nodes and Peyer's patches—may be related to the adjuvant activity.

The development of poly dUfl and other related polymers represent our first steps in an adventure that should produce new therapeutic agents for those syndromes related to failures in cellular nucleic acid metabolism. Viral disease, metabolic disease, congenital defects, aging and cancer are intimately related to inherited or acquired abnormalities in the information processing events that comprise the path from DNA to protein. The development of compounds that would correct mistakes in this information processing system and provide simple, frequent and reliable information would be a contribution that a scientifically guided industry should be able to make—a truly revolutionary advance in therapeutics.

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PHYSICS

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was elected Chairman for 1974

ABSTRACTS

Liquid Scintillation Technique for Radiocarbon Dating of Samples of High Organic Content.¹ JOHN L. LEPERA and DAVID E. KOLTENBAH, Department of Physics and Astronomy, and JOHN H. MEISER, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Design and construction of radiocarbon-dating apparatus at Ball State University is described. The technique first involves pyrolysis of the organic sample and the conversion of the carbon to acetylene, which is then trimerized over vanadium pentoxide to benzene. The radiocarbon content of the benzene is determined by liquid scintillation counting in a Beckman Model LS-100 Liquid Scintillation System. The method is particularly useful for dating organic materials of high carbon content and is being employed in a survey of peats and marls, principally in east central Indiana, and in dating various Indian site remains in Indiana. Details of the standardization of the counting technique and calculation of ages were given by Binnion, Meiser, and Koltenbah (see the Chemistry Division, p. 125).

An Optical Instrument for Viewing Near-flat Surfaces: The "Toposcope". WILLIAM W. DAVIS, 4124 North Pennsylvania Street, Indianapolis, Indiana 46205.—This instrument employs reflection from a flat or near-flat specimen surface as part of an optical system. All deviations from flatness (of the order of a few seconds of tilt) are made visible or dark. Resolution is excellent and fine structural detail can be seen in specimen surfaces where significant contour patterns exist. Surfaces as large as 5 inches in diameter may be examined and photographed with uniform detail and resolution.

The conditions of viewing include light field, dark field, and transition toposcopic modes and the full color mode for direct comparison. Use of the instrument to view lap polished surfaces of silicious stones has revealed much fine structural detail. Crystals deposited on true flats and surface distortions on liquids and gels have also been examined. Photographic examples were shown.

Thermodynamic Considerations in Devising an External Combustion Gas Turbine Engine Refuse Incinerator. GALE M. CRAIG and GERALD P. THOMAS, Department of Physics and Astronomy, Ball State University,

¹ We gratefully acknowledge partial support of this research by a grant from the Indiana Academy of Science.

Muncie, Indiana 47306.—Study and experiment indicate that, with existing technology, a modified open Brayton cycle can be used to burn common municipal refuse at atmospheric pressure and produce useful power while scrubbing the combustion product gases to remove pollutants. The hot combustion gases pass from a combustor through a turbine to a region below atmospheric pressure where they are scrubbed and cooled by mixing with water spray. The water spray and gas mixture is then exhausted to atmospheric pressure through a compressor. Although current compressor designs are workable in this application, a new design is needed which will have reduced water drag power loss.

Some New Solutions of Schrödinger's Equation in Spherical Coordinates. HERBERT H. SNYDER, Department of Mathematics, Southern Illinois University, Carbondale, Illinois 62901.—The solvability of the one-particle Schrödinger equation $\nabla^2 \Psi + K^2(E - V)\Psi = 0$ ($K = \text{const.} > 0$) by the method of separation of variables depends not only on the coordinate system, but also on the structure of the potential, V . The problem of determining all such coordinate systems, together with the required form of the potential, was solved by Eisenhart (Phys. Rev., 74:87-89). For spherical coordinates ρ, θ, ϕ , Eisenhart's potential is $V = f(\rho) + g(\theta)/\rho^2 + h(\phi)/\rho^2 \sin^2 \theta$, where f, g, h are arbitrary functions. The author applied Eisenhart's theorem to the determination of the wave functions associated with a spherical potential well, described by a piecewise-constant potential which possesses periodic dependence on the angular coordinate ϕ , as well as the usual dependence on ρ . The equation to determine the allowed discrete energy levels now takes the form of a vanishing infinite determinant. Also shown was how the problem of the wave functions associated with the potential of a dipole field, may be similarly treated.

Holography Made Easy. CATHERINE J. BASANAVICUS, PAUL R. ERRINGTON, and JACK P. COLLINS, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.—This summer, we set-up a holography laboratory at Ball State University. Holography works on the basis of interfering wavefronts. The equipment needed includes film, a laser, a stable base, dispersion lenses, and other accessories. The four types of holograms and the procedure used in making a hologram were discussed. Enough information was given so that others should be able to set-up their own holography laboratory.

Optical, Radio and Temperature Observations at the 10 July 1972 and 30 June 1973 Total Solar Eclipses

MALCOM E. HULTS, DUANE W. WARN,¹ DANIEL A. MITCHELL² and GARY D. BARTON

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Abstract

Shadow bands were detected with a multichannel photo-electric system at the 10 July 1972 eclipse. The bands were strongest in blue, weaker in red and weakest in green-yellow light. A second system showed that the light intensity fluctuation frequency consisted of a continuous frequency of approximately 6 hertz with an approximate 22 hertz frequency appearing from 50 seconds to 10 seconds before totality. A monitor at 3.85 megahertz showed that radio frequency noise began to increase approximately 22 minutes before totality and increased by at least a factor of five peaking about 4 minutes after the end of totality. An electronic thermometer showed a 10° Fahrenheit drop in temperature, the minimum occurring approximately 5 minutes after the end of totality. For the 30 June 1973 eclipse more extensive electronic detection equipment was developed. Detectors for radio frequency noise at 146.94, 50.4 and 7.5 megahertz and 550 kilohertz were used. A voltage-to-frequency converter system showed that the light level decreased from approximately 11 foot-candles shortly after sunrise to an undetectable level during totality. Ionosphere height measurements were analyzed at frequencies ranging from 0.5 to 20 megahertz showing a decrease in height during totality for frequencies ranging from 3.5 to 5.5 megahertz. Possible correlations of shadow band activity, radio frequency noise and ionosphere heights are being studied further.

Introduction

A number of interesting phenomena occur before, during and after the total phase of a solar eclipse. Many of these phenomena have not been analyzed thoroughly primarily due to the very short time period during which they occur. This paper reports observations of such phenomena at two recent eclipses.

For a few minutes preceding and following the total phase of a solar eclipse, faint light and dark bands move across the surface of the earth. Continuing observations of these shadow bands begun at the 1966 eclipse in Rio Grande do Sul, Brazil (1), and further refined at the 1970 eclipse in Greenville, North Carolina (2), a team of 14 persons set up equipment for visual, photographic and photoelectric detection of shadow bands at the 10 July 1972 eclipse at Malignant Cove, Nova Scotia. In addition, rf noise (at 3.85 mHz) and air temperature were recorded. Further continuation of our eclipse observations was accomplished at the recent eclipse, 30 June 1973, one team (M.H., D.W., G.B.) observed in Surinam, South America, and the other from aboard ship off the coast of Mauritania, Africa. The Surinam work involved measurements of the variations of intensity of rf noise at four different frequencies, plus recording of air temperature and light level.

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Ionospheric height measurements using a range of frequencies of 0.5 to 20 mHz were made by a collaborating group in Surinam and the analysis of these data is presented.

Equipment

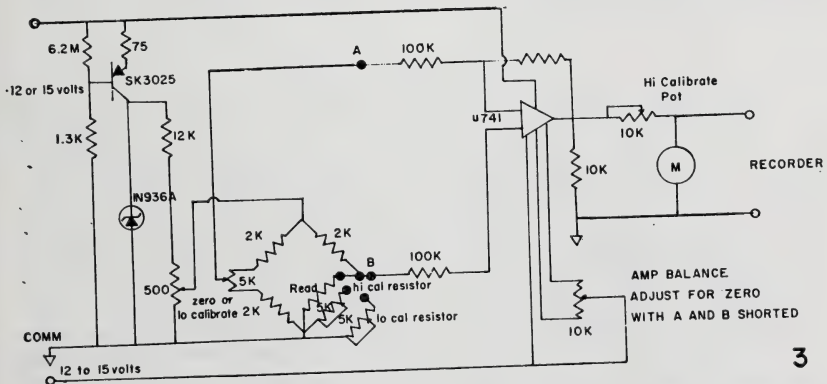
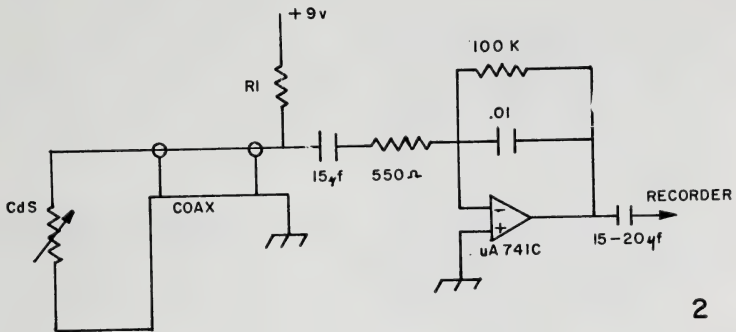
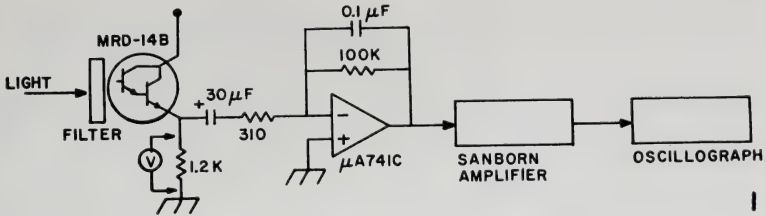
Five systems were used at the 10 July 1972 eclipse. System No. 1 was designed to determine the optical wavelength nature of the shadow bands. The photodetector for channel A was a CdS cell with no optical filter. Motorola MRD-14B Photo Darlington transistors were used on the other six channels with optical filters as follows: Channel B, blue wide-band; Channel C, red wide-band; Channel D, green wide-band; Channel E, blue-green narrow-band (5270 Å); Channel F, green-yellow narrow-band (5870 Å); Channel G, red narrow-band (6870 Å). The electronics for a single channel is shown in Figure 1. A voltmeter across the load resistor monitored the output of the transistor. The a-c coupling between the transistor and the μ A741C amplifier made it unnecessary to continually adjust for variation of total light intensity, a difficulty experienced at the 7 March 1970 eclipse (2). The capacitor feedback loop in the pre-amplifier eliminates high frequency noise generated by the detector. The outputs of the seven channels were recorded on a Brush high speed multi-channel strip chart recorder.

System No. 2 was designed to determine the light intensity fluctuation frequency composition of the shadow bands. One CdS photocell was connected to a set of eight electronic filters, each tuned to a separate frequency of light fluctuation. The filters resonated at the following frequencies with adjacent filters overlapping at 0.707 of the maximum voltage: 2, 4, 6, 8.2, 11, 15, 22 and 28.2 Hz for Channels A through H, respectively. The CdS photo resistive cell is connected to a step attenuating load resistor. The detector signal is capacitively coupled to a 40 Hz low-pass filter with the output directly fed into the eight separate band-pass filters. Each of the signals is amplified and displayed on a 100 μ A meter. The set of eight meters (with a large dial watch for timing purposes) was continuously photographed with a Super 8 movie camera.

System No. 3 consisted of two CdS photocells spaced 30 cm apart and placed in a plane perpendicular to the sun's rays and in a vertical plane. The photocells were connected to a Brush two-channel high speed strip chart recorder. The velocity of the shadow bands could be obtained by measuring the time difference of correlating points of the two recordings.

System No. 4 was a Heathkit HR-10B amateur radio receiver and a strip chart recorder. This system monitored rf noise at 3.85 mHz. This frequency was selected due to a lack of amateur radio "traffic" at this frequency. Experiencing a great amount of rf interference in our equipment at the 7 March 1970 eclipse suggested this experiment.

System No. 5 was an electronic thermometer connected to a strip chart recorder for monitoring the air temperature, before, during and after totality.



FIGURES 1-3. Photoelectric system used for detecting optical wavelength characteristics of shadow bands (System No. 1). One channel of a seven channel system is illustrated. 2) Photoelectric system for shadow band velocity, band width and band separation measurement. 3) Electronic thermometer used for measuring air temperature at the 30 June 1973 eclipse.

Seven systems (Nos. 6 through 12) were used at the 30 June 1973 eclipse. System No. 6 consisting of two detectors, each using the electronics shown in Figure 2, was connected to a dual channel Astro-Med Model 202 strip chart recorder. This experiment, which was

an advancement over System No. 3, was used to try to measure the velocity, the band width and the band separation of shadow bands.

System No. 7 was an electronic thermometer for air temperature measurement. The output of this circuit is independent of power fluctuations. The circuit, see Figure 3, is a balanced bridge using a military thermal resistor (Read). The output of the bridge and calibration circuits is fed into a balanced operational amplifier for amplification to levels suitable for meter and recorder outputs.

Systems Nos. 8, 9, 10 and 11 were designed to monitor rf noise at frequencies of 146.94 mHz (using a highly directional antenna aimed at the sun), 50.4 mHz, 7.5 mHz and 550 kHz (all three using non-directional antennas). The receivers were, respectively, a Motorola crystal controlled HA-734 receiver through a diode pump into a Heathkit Model IR-18M chart recorder, a Lafayette Model HA-750 receiver into an AIWA Model TP-707P cassette recorder and a Military Command radio receiver Model BC-453B into an AIWA Model TP-707P cassette recorder.

System No. 12, used for measuring the light level before, during and after totality, consisted of a voltage-to-frequency converter, resulting in frequencies in the audio range recorded onto a cassette tape.

In addition to using the above mentioned equipment designed and operated by our team, Mr. A. A. Sandel, Director of the Meteorological Service of Surinam, put us in contact with a group in Paramaribo who daily monitor ionospheric heights using 0.5 to 20 mHz frequencies. Photographic recordings before, during and after totality were brought back for analysis.

Results and Discussion

Strip chart recordings of the shadow bands, using System No. 1, are shown in Figure 4. Comparison of the recordings at four different time periods before totality shows the over-all change in intensity of shadow bands with time and the great complexity of the bands. Analysis of the complete recording from 600 sec before totality (-600 sec) to 35 sec before totality (-35 sec) reveals the following: Channel A (unfiltered CdS cell) showed the most activity, while Channel B (blue wide-band) was next most active and Channel C (red wide-band) was third in activity. Channel D (green wide-band) showed relatively little activity. Channel E (blue-green, 5270 Å) showed more activity than Channel G (red, 6870 Å). Channel F (green-yellow, 5870 Å) showed almost no activity. These approximate relative intensity values are shown in Figure 5. Since the shadow bands occur at approximately the same time as the flash spectrum, one might expect a direct correlation between the two which possibly is evident in Figure 5.

The recordings of System No. 1 were also analyzed for light intensity fluctuation frequencies. At all colors there was a predominate frequency of about 6 Hz for large amplitude components. These components were present all the time the equipment was on (beginning 600 sec before totality). The high frequency components were

low in amplitude and in the range of 15 to 25 Hz from 600 to 150 sec prior to totality. The high frequency components increased in frequency to as high as 50 Hz at 120 sec prior to totality in the red region. At 75 sec prior to totality the lower most dominant frequency was still 6 Hz and the higher frequency components were in the 13 to 16 Hz range. Activity on all the channels with wide band filters (and the unfiltered channel) began to decrease at about 130 sec before totality with very little activity remaining at approximately 20 sec before totality. This decrease just before totality corresponds well with previous results (2).

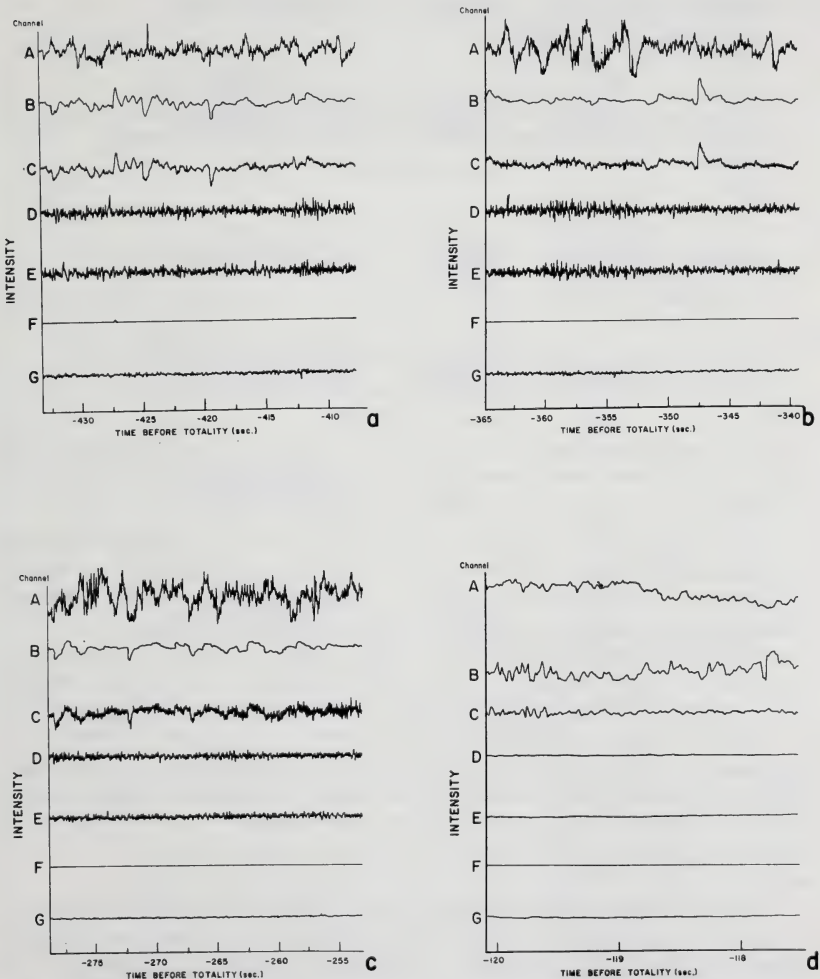


FIGURE 4. Strip chart recordings of shadow bands (System No. 1) at four different time periods (a, b, c, d) ranging from 430 sec to 118 sec before totality. (Solar eclipse, 10 July 1972, Nova Scotia).

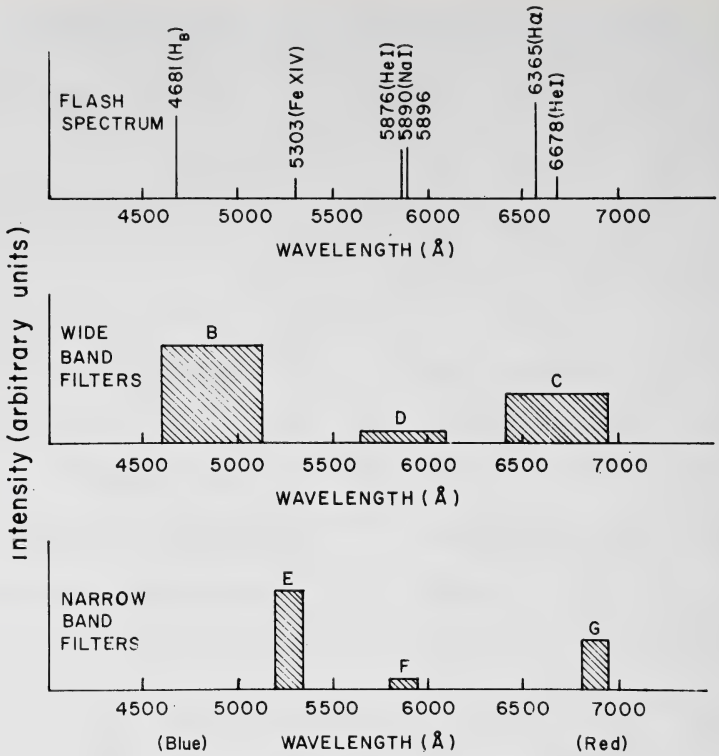


FIGURE 5. Shadow band light fluctuation intensity vs. optical frequency as obtained with System No. 1. Channel letter is noted above each bar. (Solar eclipse, 10 July 1972, Nova Scotia).

The Super 8 movie of System No. 2 was visually analyzed and the readings of six times (at 20-sec intervals prior to totality) are shown in Figure 6. Frequencies of 2 to 8 Hz remained fairly constant throughout the total time the movie was taken. This corresponds with the results of System No. 1. At about 22 Hz the intensity was very low at first but then increased considerably about 50 sec before totality and remained strong to about 10 sec before totality. This component at about 22 Hz may correspond to the usual visual shadow band phenomenon. For example, at the 7 March 1970 eclipse in Greenville, N.C., one group measured the velocity of the bands, as they moved across a shadow band screen, to be approximately 2 m/sec and estimated the spacing of the bands (center to center distance) to be 10 cm which gives a frequency of about 20 Hz.

The two channels of System No. 3 recorded shadow bands with features that correlate well with the results of Systems Nos. 1 and 2. However, there are no obvious correlations between the two recordings themselves and thus no velocity measurements were possible.

The strip chart recording at 3.85 mHz (System No. 4) shows that rf noise began to increase about 22 min before totality and increased

by an estimated factor of five times normal background peaking approximately 4 min after the end of totality.

Air temperature readings were taken every 5 min from the original strip chart recording (System No. 5) and replotted as shown in Figure 7. This shows a 10° F drop in temperature during the eclipse. The minimum temperature occurred approximately 5 min after the end of totality. The odd shape of the curve after totality was likely due to a varying cloud cover.

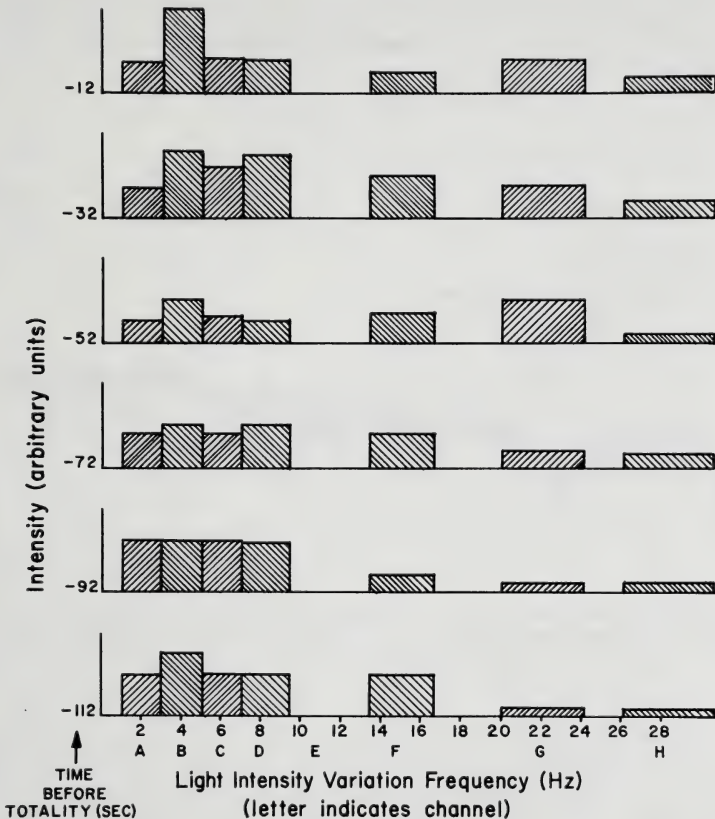
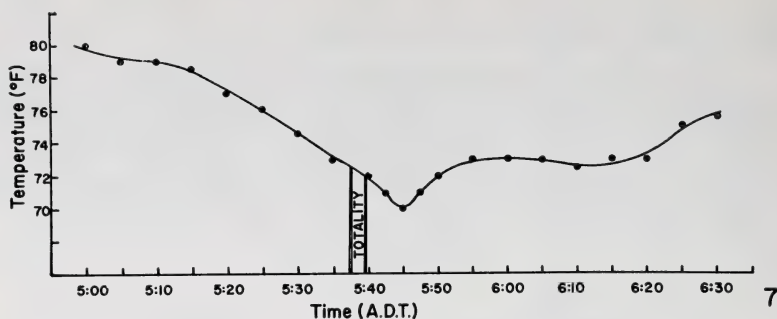


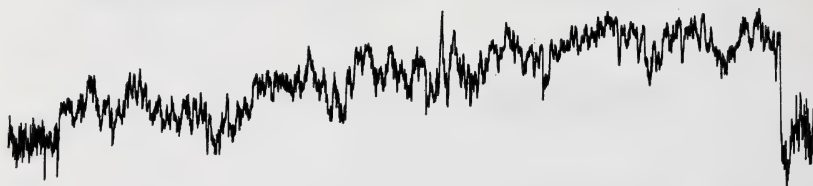
FIGURE 6. Shadow band intensity of light variation vs. frequency of light intensity variation at different times prior to totality, System No. 2. (Solar eclipse, 10 July 1972 Nova Scotia).

The shadow band velocity experiment, System No. 6, consisting of two detectors and a dual channel strip chart recorder, gave no indication of shadow band activity.

System No. 7, used to measure air temperature, indicated only a slight interruption in the usual rate of increase of temperature after sunrise.



Total Solar Eclipse
 30 June 1973
 South America
 50 sec / inch through diode pump



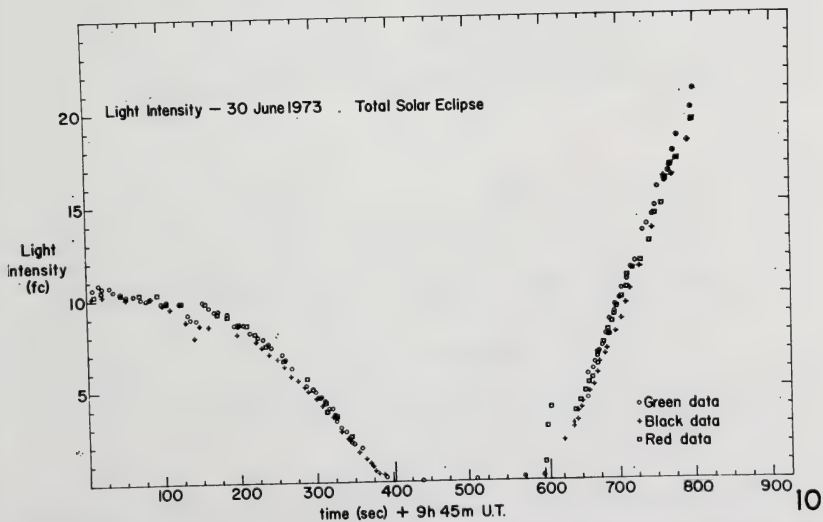
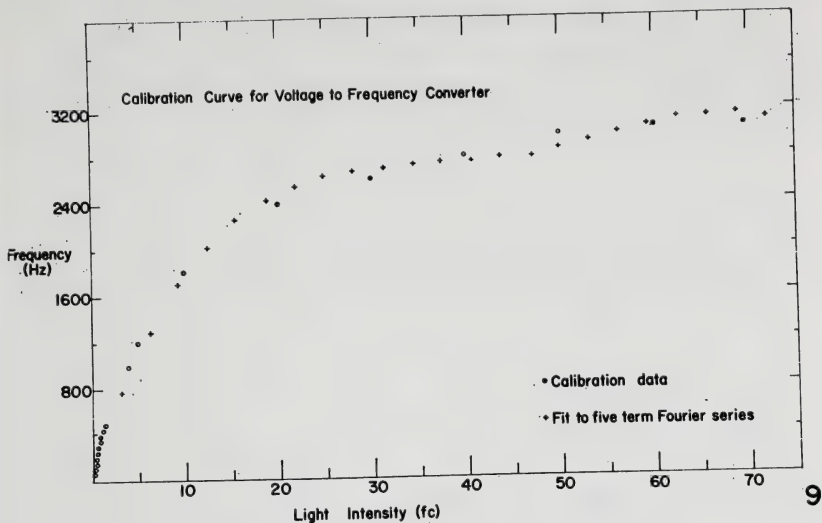
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FIGURES 7 and 8. Air temperature vs. time during the solar eclipse, 10 July 1972, in Nova Scotia. Temperature readings taken from a continuous strip chart recording of an electronic thermometer. 8) Recording of rf noise before, during and after totality at 7.5 mHz. (Solar eclipse, 30 June 1973, Surinam).

The rf noise experiments, Systems Nos. 8, 9, 10, 11 gave indications of changes of rf noise intensity before, during and after totality. There is some indication that rf at 146.94 mHz (antenna directed toward the sun) decreased during totality while the rf detected by the non-directional antennas (at 50.4 mHz, 7.5 mHz, and 550 kHz) increased. Due to problems of interference from the portable electric generator the data are marginal. Figure 8 shows a recording of rf noise before, during and after totality at 7.5 mHz. As can be seen there is an increase and then a decrease in the rf energy.

System No. 12 was calibrated by simultaneously shining a variable light source onto the detector of the system and onto a photometer. A range of light levels gave a range of audio frequencies which was compared audibly with a calibrated audio signal generator. The resulting calibration curve is shown in Figure 9. The cassette tape record-

ing made at the eclipse was then played and the audio frequency was compared with the audio signal generator at specific times. This was done three times, indicated as black, green and red data. The resulting graph of light level is shown in Figure 10 which shows that the light level decreases from approximately 11 foot-candles shortly after sunrise to an undetectable level during totality with the expected increase after totality.



FIGURES 9 and 10. Audio frequency vs. light intensity for the voltage-to-frequency converter determined by an audio signal generator and photometer system. 10) Light intensity vs. time for the 30 June 1973 solar eclipse in Surinam, South America.

The photographic recordings of the ionospheric heights before, during and after totality were analyzed by measuring the heights for every half mHz over a time span of 28 min (Fig. 11). Generally the ionospheric height that reflects certain frequencies is different than the ionospheric height that reflects other frequencies. A decrease in the ionospheric heights for frequencies ranging from 3.5 to 5.5 mHz at the time of totality is quite apparent while there is little change from 6.0 to 7.5 mHz.

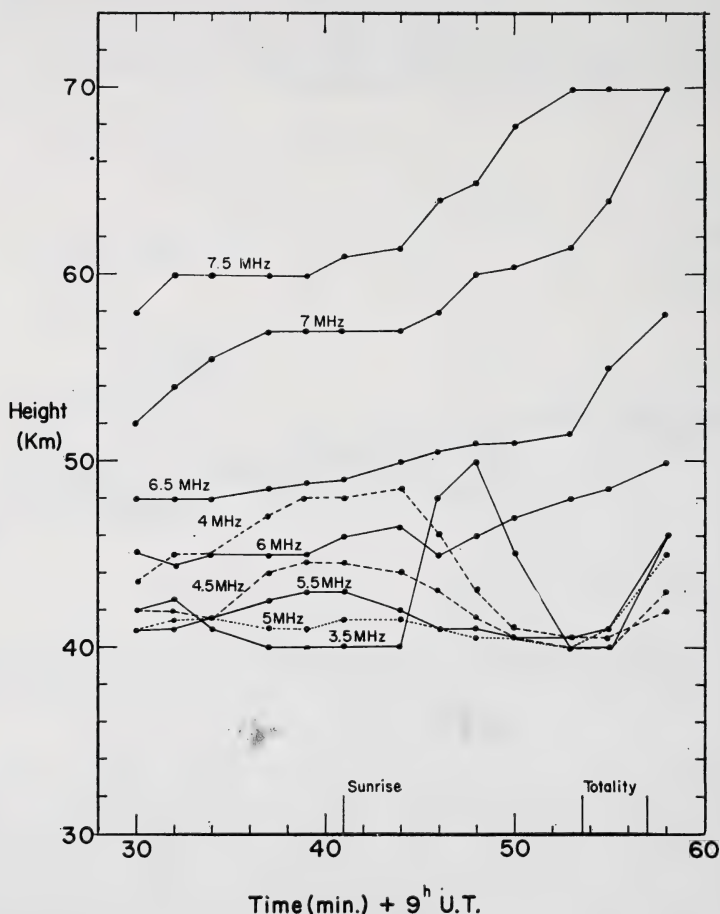


FIGURE 11. Ionospheric height vs. time for rf frequencies ranging from 3.5 mHz to 7.5 mHz. (Solar eclipse, 30 June 1973, Surinam).

Conclusions

The conclusions from this eclipse work are: 1) shadow bands are strongest in blue and weakest in green-yellow light; 2) the light intensity fluctuation frequency is fairly steady at about 6 Hz with a frequency of approximately 22 Hz occurring very near totality; 3) comparison of

four eclipse observations shows that haze greatly reduces shadow band visibility; 4) radio frequency noise increases using non-directional antennae and perhaps decreases using antennae directed toward the sun; 5) ionospheric heights vary little using frequencies from 6.0 to 7.5 mHz but from 3.5 to 5.5 mHz the eclipse lowers the heights considerably. Correlations of shadow band activity, radio frequency noise and ionospheric heights may be found as further study is made.

Acknowledgments

Personnel who helped with the eclipse work were Lloyd and Laura Mitchell, Beverly Warn, Sandra Barton, Gary and Willa Tomlinson, Joyce, Carolyn, Richard and Stewart Hults in Nova Scotia and Dr. F. Liems, A. A. Sandel, Mr. Isselt, Mr. Ori, Mr. Banwarie, L. W. Fung, F. R. Wadilie and T. Fooh in Surinam.

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2. ———, R. D. BURGESS, D. S. MITCHELL, and D. W. WARN. 1971. Visual, photographic and photoelectric detection of shadow bands at the March 7, 1970, solar eclipse. *Nature* 231:255-258.

Shipboard Visual and Photographic Observations of the 30 June 1973 Total Solar Eclipse

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Abstract

Equipment was developed for photographic, photoelectric and visual detection of shadow bands, for photographing the flash spectrum and the corona at the total solar eclipse of 30 June 1973. Observations were made aboard the French ship, the M.S. Massalia, off the west coast of Mauritania, Africa. Very good photographs of the total eclipse are presented.

Introduction

Eclipses afford opportunities for various studies associated with the sun, the moon and the earth's atmosphere. At each eclipse new information is obtained and each eclipse is different which adds great interest to the subject. In this project equipment for photographic, photoelectric and visual detection of shadow bands and for photographing the flash spectrum and the corona was developed. Air freighted heavier equipment did not arrive on time but very good photography of the eclipse itself was obtained using hand carried equipment aboard the French ship, the M.S. Massalia, off the west coast of Mauritania, Africa, where the eclipse lasted for 5 min and 40 sec.

Photographic Results

Figure 1 shows the outer corona in a 1/15th-sec exposure (upper left) and the inner corona in a 1/125th-sec exposure (upper right). A prominence is visible at the top of the 1/250th-sec exposure (bottom left) while coronal streamers and a prominence are seen in a 1/250th sec exposure (bottom right).

Figure 2 is a sequence of photographs taken approximately one second apart as the sun emerges. A prominence is visible (left), followed by the chromosphere shining through the valleys of the moon (second from left). Next are seen Baily's Beads, followed by a view of the chromosphere emerging. The first three exposures were 1/60th sec, the fourth 1/125th sec and the last 1/250th sec.

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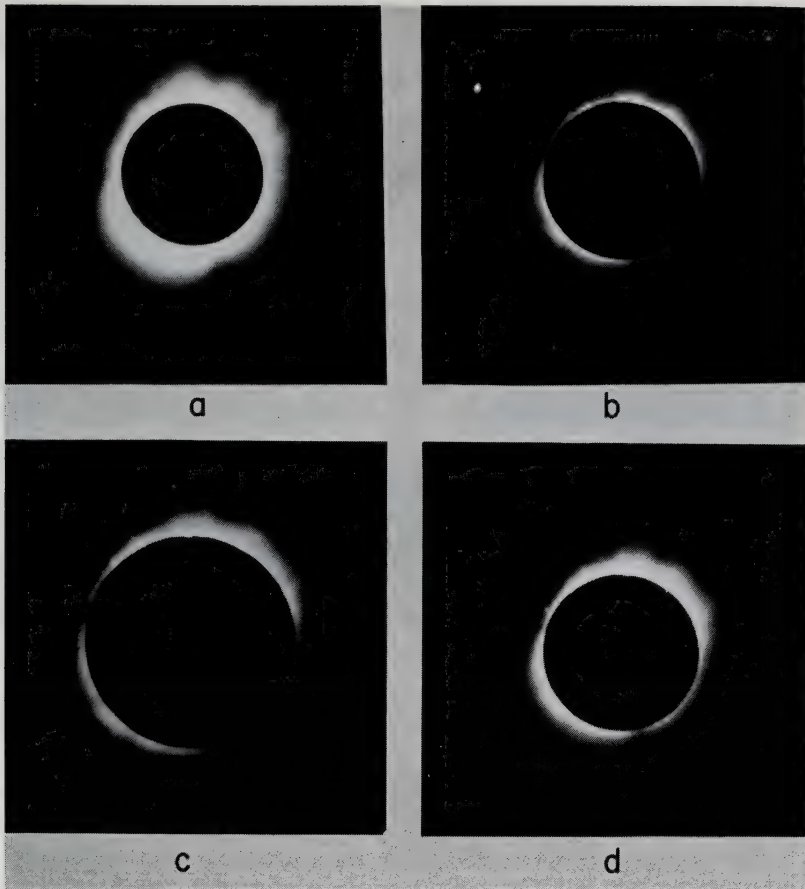


FIGURE 1. a) Outer corona; b) Inner corona; c) Prominence; d) Coronal streamers and a prominence.

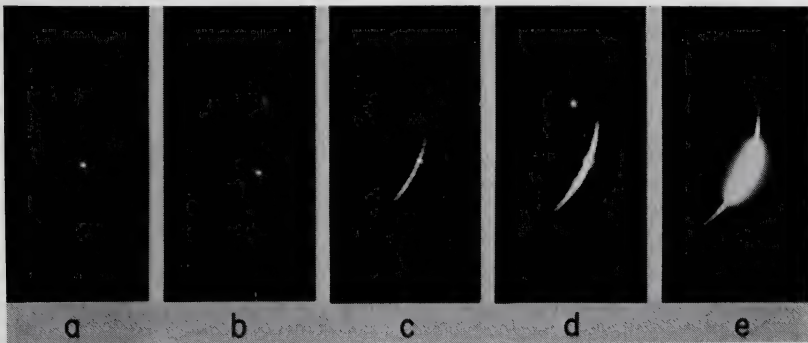


FIGURE 2. a) Single prominence; b) Chromosphere shining through the valleys of the moon; c) Bailey's Beads; d) First emergence of the chromosphere; e) Chromosphere shining brightly.

The diamond ring effect is seen in Figure 3. The diamond ring is quite difficult to photograph due to the very short period of time that this phenomenon occurs.

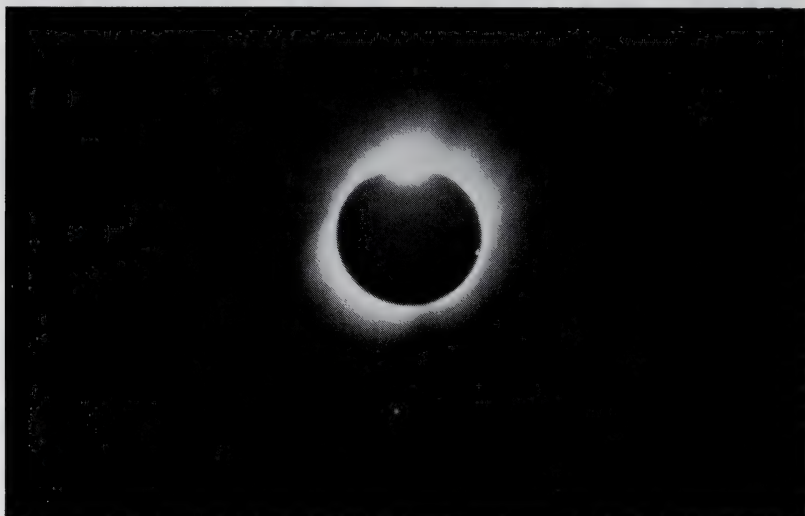


FIGURE 3. *Diamond ring effect.*

The photographs in Figures 1 and 3 were taken by one of us (K.B.) using a Praktica Nova camera with a 400 mm focal length, $f/6.3$ Spiratone telephoto lens. The sequence in Figure 2 was taken by another member of the team (D.M.) using a Miranda "F" camera with a 500 mm focal length MTO lens and a 2X teleconverter giving an effective focal length of 1000 mm at $f/16$.

Comments and Conclusions

Observing aboard ship produced some unique problems and advantages as compared with the usual land based observations. One obvious advantage is the mobility of already prepared set-ups which is valuable for avoiding adverse weather conditions. Disadvantages are poor visibility due to sun haze, the roll of the ship, vibrations due to the ship's engines and smoke from the engine smoke stacks.

The unfortunate miss-routing of equipment afforded the opportunity to concentrate on photography with relatively inexpensive hand carried equipment. For example, the Spiratone 400 mm focal length lens costs only approximately \$40.

The photographs presented in this paper show that quite good results can be obtained by using ordinary cameras with relatively inexpensive telephoto lenses.

The Terre Haute Astronomical Object List (THAOL) Program: A Public Relations and Teaching Resource

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Abstract

This paper is a discussion of the features of a computer program which lists all of the astronomical objects available for observation by any given instrument under any given sky conditions, at any time and date, for any spot on the earth.

Observations from a small observatory located in a large city are hindered by variable atmospheric conditions more than by small apertures. Such an observatory is best suited for public relations and education, but research depends upon the determination in advance which objects are most easily studied from such a location. A list of observable objects can be compiled if numerical parameters describing normal atmospheric conditions and instrumental limits are known. Measurements for the Indiana State University Observatory indicate that on good nights the limiting magnitude of the 6-inch refractor is 12 for objects more than 45° above the horizon, but objects of second magnitude cannot be seen below about 20° altitude above the horizon. On nights of poor visibility, this second magnitude limit reaches the zenith, and although the sky is not cloudy, only the moon and bright planets can be seen with the naked eye.

With observational limits well defined, a list of visible objects until recently has been too detailed an undertaking to prepare repeatedly. The repetitive nature of the calculations required suggests the use of high-speed data processing equipment. The above observations, standard lists of astronomical objects, and unlimited run time on the IBM 360 computer at Indiana State University have been combined to produce the Terre Haute Astronomical Object List, THAOL for short. The computer scans the catalog of objects, computes their altitudes for the desired location and date, and prints out lists of those objects which can be seen with the prevailing atmospheric conditions and available instrumentation.

The object list is divided into six sub-lists: double stars, open and globular clusters, nebulae and galaxies are taken from lists in the *Observer's Handbook* (1). We intend to supplement these lists with the *New General Catalog* (2) when detailed lists of faint objects are required. The list of moving objects must be re-punched for each time period; in particular, the Moon's location must be changed every hour.

Most of the program converts non-decimal numerals to decimal numbers, and prints the corrected numerals in a useful format. A block diagram of the program (Fig. 1) illustrates the two kinds of input cards: parameter cards and object lists. The parameters of position on the earth, date and time, observational limits, and the name of

the institution or place of observation are included on one card, which is entered before each deck of object cards. From these parameters, local sidereal time is computed from formulas familiar to the beginning astronomy student:

- 1) Local Sun Time = Local Standard Time—[(Local Longitude—Standard Time Meridian) $\times$ (1 Hour/15°)]¹
- 2) Sidereal Time = Local Sun Time + [2 hours $\times$ (current month—9)] + [4 min. $\times$ (date—23)]

The azimuth and altitude of each object can be obtained by:

- 3) Hour Angle = Sidereal Time—Right Ascension
- 4) Zenith Distance = $\arccos [\sin(\text{latitude}) \times \sin(\text{declination})] + [\cos(\text{latitude}) \times \cos(\text{declination}) \times \cos(\text{hour angle})]$
- 5) Altitude = 90°—Zenith Distance
- 6) Azimuth = $180^\circ + \arcsin [\sin(\text{hour angle}) \times \cos(\text{declination})] \sin(\text{zenith distance})$

For the computed altitude, a minimum observable magnitude is computed, and is compared with the visual magnitude of the object. If an object is too faint for its altitude, it is omitted from the list. If an object is bright enough to observe, it is placed on one of two lists, depending on whether it is east or west of the meridian. Two lists are essential when an equatorial telescope mounting is in use, as the telescope must be repositioned to cross the meridian. A third list, which consists of those planets above the horizon but not well placed for observation is also collected. When a complete set of objects has been processed, lists of the visible objects in the set are printed before the next parameter card is read.

Although only right ascension, declination and magnitude are used in computation, each object card contains alternate names, size of object, orbital details, distance from the earth, light time, and other important features. For some objects the information is packed tightly on the 80 character card, but is separated into readable units on the printout, which is 130 characters wide. Changes in the list can be made at the telescope, and new information can be added to the object list before it is run through the computer again. When running smoothly, the 6 object lists are scanned and printed in less than 4 min.

Besides observational work, this program can be useful in the laboratory. Lists calculated for differing sky conditions at one location can be compared, and the optimum telescope size for any site can be determined with a minimum of site-testing. Lists assuming the same atmospheric conditions can be run for several latitudes and compared, providing a graphic display of how latitude affects the local horizon. For public viewing nights, it is reassuring to have a complete list of objects that are observable without difficulty.

With the success of the THAOL program, we have been encouraged to devise other computer-produced observing aids. Our ephemeris of sunrise, sunset, beginning and end of evening and morning twilight, moonrise and moonset has been expanded to include a brief astro-

¹ For a first approximation, the equation of time can be left out.

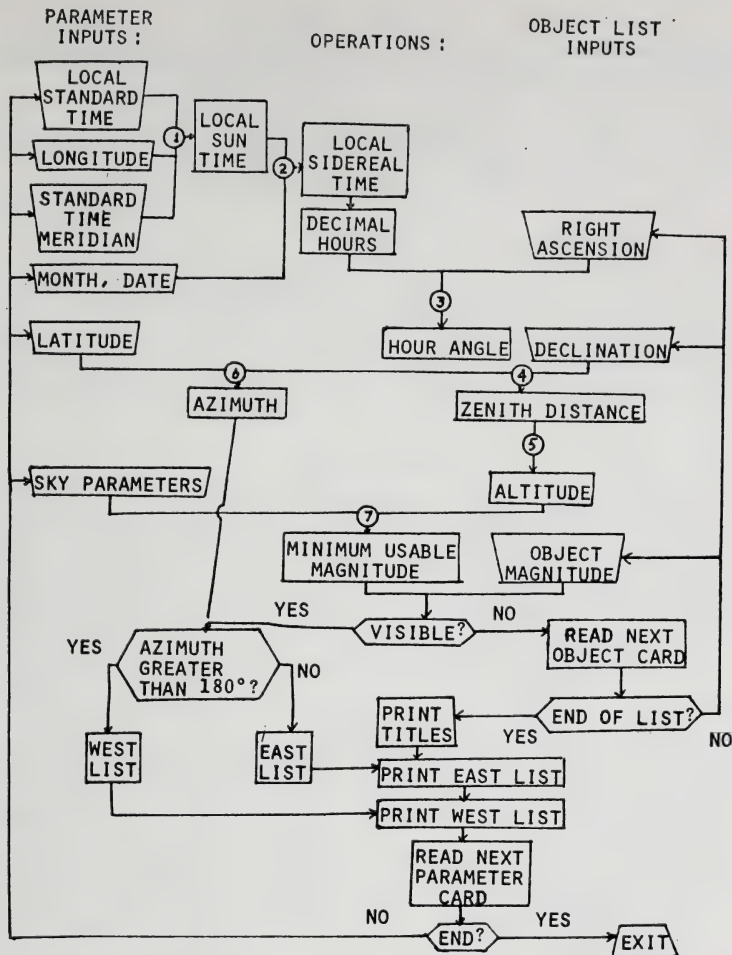


FIGURE 1. The Terre Haute astronomical object list program block diagram.

nomical calendar. The ephemeris for observations of Jupiter and Mars in the *American Ephemeris and Nautical Almanac* (3) has been used to compute hourly positions of Jupiter's Red Spot, central Equatorial Zone, fifth satellite, and the meridian of Mars. These simple programs are of great help to our observers, and are available on request. For those of you without computing facilities available, the Indiana State University computing center will run an occasional list if the necessary parameters are supplied: latitude, longitude, name and local standard time meridian of the observatory or site, lowest altitude at which second magnitude stars are visible, altitude above which objects are visible to the limiting magnitude of the available instruments, limiting magnitude of those instruments, and dates and times for which the information is required.

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Daily and Weekly Changes in Total Suspended Particulate Matter Concentrations at Anderson, Indiana

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Abstract

Hourly total suspended particulate concentrations for the period August 10—September 14, 1973, at Anderson, Indiana, were analyzed to illustrate the hourly and daily variation in urban air pollution. Hourly and daily changes in air quality as measured by hourly particulate concentrations are identified; comparisons are made between these measurements and the hourly and daily changes in industrial activity and meteorological conditions. These comparisons are the basis for the proposed reasons for the recorded changes in hourly and daily air quality.

Introduction

Urban air pollution concentrations vary from day to day and from hour to hour during the day. In general, high levels of atmospheric pollution are associated with stable, stagnant meteorological conditions, while low levels of pollution are related to more unstable conditions. However, normal local meteorological changes coupled with variations in human activity in a given urban area can lead to substantial periodic patterns in air pollution concentrations.

These patterns must be considered when setting up any air pollution monitoring system. For example, the least biased estimate of the annual mean of the suspended particulate concentrations at Indianapolis, Indiana, can be obtained by sampling on Fridays, as opposed to sampling on any other day of the week (3). Since the City of Anderson has recently begun an air pollution monitoring program, it was appropriate to examine the daily and hourly variations in suspended particulate matter in this urban setting as an assistance in setting up the proper sampling schedule at the outset of the program.

Data and Methods

The usual method of measuring suspended particulates is by drawing a high volume of air through a filter paper in a sampler. The difference in the mass of the filter before and after sampling is used to determine the particulate concentration in micrograms per cubic meter of air. A 24-hour sampling period is normally used.

In this study I looked at hour-by-hour variations in suspended particulate rather than just 24-hour variations; a paper tape sampler was used instead of the high volume sampler. In this instrument air is drawn down a 0.5-inch intake pipe and past a filter tape upon which the particulate matter is deposited. After a set sampling period (1 hour in this study) the tape is automatically advanced and sampling is begun at a clean position on the tape. The dirt spots thus produced are evaluated by measuring the difference in light transmission through

the tape between a clean and sample spot. This optical density (O.D.) is then changed into the standard unit coefficient of haze (COH) according to the formula:

$$\text{COH/1000 feet} = \frac{\text{O.D.} \times 10^5 \times A}{V}$$

where $A = \text{area of the dirt spot in square feet} = 0.00136 \text{ ft}^2$
 $V = \text{volume of air sampled in cubic feet} = 24 \text{ ft}^3$

$$\text{O.D.} = \frac{1}{\text{per cent light transmission}}$$

A COH unit of 1 or below represents a clean outdoor condition, while a COH unit of 10 is an extremely dirty condition. Although the high volume sampling method is preferred for legal purposes, recent studies indicate that the paper tape sampler is a very reliable method for determining short time interval variations in studies such as this one (2).

The sampler was placed on the roof of Hartung Hall on the Anderson College campus, which is generally down wind from Anderson industry. Sampling began at noon on August 10, 1973. Except for the down time needed to change the tapes, the sampler ran continuously through noon on September 14, 1973, a period of 5 weeks. A total of 828 sample spots were collected and evaluated during the study. The overall mean COH unit was 0.59, with 1.53 being the highest COH unit measured. Mean values for each day of the week and each hour of the day were calculated, and these data were subjected to an analysis of variance.

Results and Discussion

The general weather pattern during this study was anticyclonic in nature, as expected for this time of year from climatic information (1). Such stable conditions should lead to some of the highest air pollution concentrations of the year. The 0.59 mean COH unit found in this study indicates that Anderson has relatively clean air, especially for an industrial urban community. This substantiates the preliminary findings of the Anderson Air Pollution Control Department (J. Hoenstine, pers. comm., 1973).

Table 1 shows that the average suspended particulate in Anderson is not constant from day to day during the week. An analysis of variance test gave an observed F ratio of 6.77 which is significant at both the 0.01 and the 0.05 levels. A subsequent Newman-Keuls test (Anderson, V. L., and R. A. McLean, unpubl. data) shows that, at the 0.05 level, Sunday and Monday are significantly lower than Thursday, Friday, and Saturday, while Friday is significantly higher than Sunday, Monday, Tuesday, and Wednesday. The data indicate a slight build-up in particulate pollution during the course of the work week with a subsequent decline during the week-end when less industrial activity occurs. The data also show that the least biased sampling days are Tuesday and Wednesday, since they have the mean daily values closest to the reported weekly mean value.

TABLE 1. *Mean daily values of total suspended particulates for each day of the week at Anderson, Indiana, August 10 — September 14, 1973.*

Day	Mean COH Value
Sunday -----	.50
Monday -----	.53
Tuesday -----	.58
Wednesday -----	.57
Thursday -----	.63
Friday -----	.69
Saturday -----	.63
Weekly $\bar{X}$ -----	.59

Table 2 shows the diurnal variation in the particulate concentration in Anderson. An analysis of variance test on this test gave an observed F ratio of 9.54 which is also significant at both the 0.01 and the 0.05 levels. The Newman-Keuls test in this case confirms that, at the 0.05 level, the particulate concentration during the 6:00 PM to 10:00 AM period is significantly higher than the particulate concentration during remaining hours of the day. Meteorological factors are the prime reason for this pattern, since in Anderson nearly all industrial activity takes place on a round-the-clock basis. During the daylight period the sun's heat increases the convectonal mixing in the atmosphere and the winds are relatively strong, leading to a reduction in pollution concentrations at the ground. As the sun goes down, however, the winds diminish and the convectonal activity ceases or at least is reduced. The result is an increase in pollution concentrations at the ground during the night time period.

TABLE 2. *Mean hourly values of total suspended particulate for each hour of the day at Anderson, Indiana, August 10 — September 14, 1973.*

Time Interval, E.S.T.	Mean COH Value	Time Interval, E.S.T.	Mean COH Value
0000-0100	.71	1200-1300	.42
0100-0200	.71	1300-1400	.43
0200-0300	.79	1400-1500	.44
0300-0400	.67	1500-1600	.41
0400-0500	.64	1600-1700	.42
0500-0600	.71	1700-1800	.44
0600-0700	.74	1800-1900	.58
0700-0800	.62	1900-2000	.61
0800-0900	.66	2000-2100	.66
0900-1000	.55	2100-2200	.69
1000-1100	.45	2200-2300	.68
1100-1200	.43	2300-2400	.69
Daily $\bar{X}$			

Conclusions

From the measurement of total suspended particulate during the period August-September 14, 1973, I conclude that daily and diurnal variations are significant for Anderson, Indiana. I would expect similar results for other sampling periods during the year except that the exact days of significance might shift from season to season. Therefore, if periodic sampling of air pollutants on fixed days of the week is to be practiced in Anderson, proper procedures must be used or a seriously biased estimate of air quality may result.

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Anechoic Chamber Design for Microwave Research

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Abstract

An anechoic chamber was constructed for precise microwave exposure conditions. Construction and calibration procedures are described. Use of the chamber in several experiments demonstrated consistent operation of the generator and reproducible exposure conditions.

In recent years microwave technology has expanded rapidly and its use has become widespread in military and industrial applications and in commercial and home food preparation. The increasing potential for injury to personnel and the general public has stimulated research and discussions concerning the biological effects of microwave radiation. Much of the research reported in the literature was conducted under poor exposure conditions and lacked adequate dosimetry. This paper describes the construction and calibration of an anechoic chamber designed to give a uniform, reproducible microwave field for biological and dosimetric studies.

Microwave Generation System

The microwave power generation system is shown in Figure 1. The generator, Model HI 1200, and power control unit, Model HI-1001-X, were obtained from Holaday Industries, Hopkins, Minn. The generator produced 0.2 to 1.5 kilowatts of 2450 MHz continuous-wave micro-

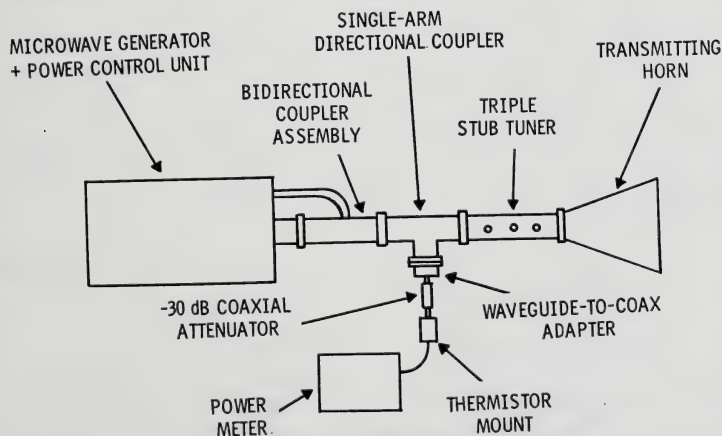


FIGURE 1. Microwave power generation system.

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wave radiation which was delivered to the anechoic chamber by WR-284 waveguide. A constant fraction of forward power was coupled out of the waveguide by a bidirectional coupler. This power was rectified and used by the power control unit to regulate the output of the generator.

A single arm directional coupler was used to extract a constant portion of the forward power. This power was attenuated (Model 771-30, Narda Microwave Corp., Plainview, N.Y.) before being measured by a thermistor mount (Model 478A, Hewlett, Packard, Palo Alto, Cal.) and power meter (Hewlett-Packard Model 432A). A triple stub tuner (Holaday Model HI-1004) was used to obtain maximum transfer of power from the generator to the anechoic chamber. The wave was transmitted into the chamber by a Narda Model 644 standard gain horn.

Anechoic Chamber Construction

The frame for the anechoic chamber was constructed from 2-inch x 4-inch pine stock and, except for the bottom, was lined with $\frac{3}{4}$ -inch plywood. The outside of the plywood was lined with aluminum foil before it was attached to the frame to prevent leakage of microwave radiation from the interior of the anechoic chamber. The foil was lapped and then stapled with metallic staples to the plywood walls of the chamber. The inside dimensions were 10 feet x 8 feet x 7 feet. A door 6 feet x 2 feet was positioned in one of the plywood panels on a side wall immediately adjacent to the back wall of the chamber. A hole was cut for the insertion of the transmitting horn in the geometrical center of the front wall so the antenna boresight would coincide with the horizontal axis of the chamber. The horizontal axis passed through a point which was located 3.5 feet from the top and bottom and 4 feet from each side wall panel.

The frame of the chamber was designed to allow ambient air to circulate under the chamber. The bottom of the chamber was lined with $\frac{1}{4}$ -inch pegboard to allow air to be drawn up into the chamber by an exhaust fan which was located outside the chamber above the back wall where most of the radiated power was dissipated as heat. Temperature analysis with thermistor beads showed that the exhaust fan maintained a range of 21°C to 25°C with the generator on nearly full power for 1 hour.

Anechoic material obtained from Eastern Microwave Corp., Winchester, Mass. was connected to the plywood panels with thermoplastic glue. The two sides, the ceiling and the floor were completely covered with -40 decibel (db) anechoic material except for a 1-foot wide border around their perimeters which was lined with -30 db anechoic material. The back wall was completely covered with -40 db anechoic material except for a 6-inch border around its perimeter which was lined with -30 db anechoic material. The front wall through which the transmitting antenna entered the chamber was completely covered with -30 db anechoic material. Three sections of 2-feet x 2-feet -40 db walk-on anechoic material were used in the floor to support polystyrene blocks

which were utilized to support samples irradiated in the quiet zone. The floor blocks also supported the weight of a person.

A microswitch was connected to the door of the chamber in a manner to cause an open circuit when the door was opened. The microswitch was connected to the interlock jack in the power control unit. When the door was opened (causing an open circuit) the generator immediately ceased rf generation. The door and interlock could not be closed from inside the chamber. This system minimized the possibility that a person would be inside the chamber or be in the process of entering it while the generator was operating.

Calibration of Single-Arm Directional Coupler

To determine the directivity of the single-arm directional coupler a flap attenuator was placed in the waveguide assembly between the triple stub tuner and the transmitting horn. The single-arm directional coupler was first oriented so that it monitored the reflected power from the ideal load formed by the horn and the flap attenuator. The depth of insertion of the resistive card flap in the attenuator was adjusted to minimize the reflected power as monitored on the power meter. The three threaded stubs in the triple stub tuner were adjusted until the reflected power was at a minimum. The orientation of the coupler was then changed to monitor the forward power. Then the horn and the flap attenuator were tuned to the generator, and the condition of zero reflected power was closely approximated. The condition of zero reflected power was assumed in the determination of the directivity. The directivity was calculated to be -40.62 ± 1.45 db.

The coupling factor of the single-arm directional coupler was determined by removing the flap attenuator from the waveguide assembly and connecting the transmitting horn directly to the triple stub tuner. The positions of the three stubs in the triple stub tuner were varied until the power reflected from the transmitting horn was minimized. A Narda 8110 microwave survey meter was used to measure the power density 92 inches from the transmitting horn along its boresight. The power incident on the coupler from the generator was calculated from the measured power density, the gain of the horn, and the distance from the horn where the power density was measured. The power which was coupled out of the forward wave was calculated utilizing the known attenuation value of the -30 db coaxial attenuator and the power as indicated by the thermistor mount and power meter. The coupling factor was computed to be -31.72 ± 1.45 db.

Amplitude Modulation of Generator

A coaxial patch cord connecting the forward power diode and the forward power jack of the power control unit was separated approximately in the middle, and a BNC tee was inserted. The voltage from the BNC tee was connected to an oscilloscope by a length of coaxial cable. The waves were smooth and very slightly skewed to the right. There were no jagged deviations or other anomalies to indicate moding. The output waveform had 120 Hz modulation.

Fundamental Frequency of Generator

A pyramidal antenna identical to the irradiating antenna was connected to a section slotted WR-284 waveguide 16.25 inches long. A Hewlett-Packard 5082-2800 microwave mixer diode was positioned with a plexiglas carriage in the center of the slot and perpendicular to the long side of the waveguide. Approximately 0.5 inch of lead wire was attached to each end of the diode. The wire leads acted as a dipole antenna. The voltage developed by the diode during rectification was monitored by two small wires attached to the leads of the diode. The end of the receiving waveguide assembly was open circuited to cause the minima in the standing wave structure to be better defined. The rectified voltage from the diode was monitored on a volt-ohm meter. The plexiglas carriage containing the diode was slowly moved along the slot in the waveguide section and the positions of two adjacent minima were located. The guide wavelength was found to be 22.90 ± 0.1 cm. The free space wavelength and the frequency of the microwave power source were calculated to be 12.207 cm and 2457.67 MHz, respectively.

Anechoic Exposure Facility Calibration

A Narda survey probe with a 25-foot cord was used to determine power density and inverse square law behavior of the radiation pattern from 18 inches to 106 inches from the horn along boresight. The tips of the anechoic material on the back wall of the chamber started at 106.25 inches from the horn. The power density measurements made along boresight showed inverse square law dependence for distances of 56 to 100 inches. When the E-M survey probe came closer than a wavelength (about 5 inches) to the tips of the anechoic material on the back wall of the chamber, the radiation pattern departed from the inverse square law behavior and exhibited maxima and minima. Thus, no samples to be irradiated should be placed closer than one wavelength to the back wall.

Conclusion

Several studies were conducted using this anechoic chamber for exposure of various materials. Exposure conditions were easily reproduced and the system operated consistently. Temperature inside the chamber increased 4°C when the generator was operating at full power for extended time periods, but the microwave intensity was much higher than intensities normally used.

PLANT TAXONOMY

Chairman: THEODORE J. CROVELLO, Biology Department,
Notre Dame University, Notre Dame, Indiana 46556

THOMAS R. MERTENS, Department of Biology,
Ball State University, Muncie, Indiana 47306,
was elected Chairman for 1974

ABSTRACTS

A Numerical Taxonomic Study of Some North American Species of *Pinus*. CHAD P. MCHUGH, Department of Biology, University of Notre Dame, Notre Dame, Indiana 46556.—A study of the relationships among 36 species of North American pines was carried out using the methods of numerical taxonomy. The study was based on 39 morphological, anatomical, and ecological characters which were selected from five treatises on the Coniferae. A similarity coefficient was generated for each possible pair of species to give a numerical estimate of species relationships. Graphic summaries included a phenogram and a principal components analysis to show clustering of the pines into groups of high similarity. They also revealed the relationships among these groups. Results agreed with traditional classifications, dividing the genus into the hard or yellow pines (*Diploxylon*) and the soft or white pines (*Haploxylon*). There was a relatively high similarity between the five needle pines and the Pinyons which had been considered separate groups. In particular, the close relationship and the similarity of ecological and habit characteristics of *Pinus albicaulis* and *P. flexilis* to the Pinyons suggest that they may be intermediate forms between the Pinyons and the other five needle pines. The study gave ideas of similarity relationships among species and among groups of species which would be difficult to ascertain with traditional taxonomic methods.

A spontaneous hybrid of *Capsicum annuum* var. *minimum* and *Capsicum frutescens*. CHARLES B. HEISER, Jr., Department of Botany, Indiana University, Bloomington, Indiana 47401.—On a visit to El Salto, Escuintla, Guatemala, in 1970 I found *Capsicum frutescens* L. to be fairly abundant as a weed in the flower gardens of Sr. R. Dorion. About 200 meters away *C. annuum* var. *minimum* (Miller) Heiser was a common weed in the yard of the Organization of Tropical Studies house. Inspection revealed that the plants of *C. frutescens* were rather uniform; the same was true of *C. annuum* var. *minimum* except for two of the 20 plants examined. One of these appeared to be fairly typical of *C. annuum* var. *minimum* except for the calyx which was somewhat like that of *C. frutescens*; the other (7105) was much taller than the other plants with more elongate fruit approaching that of *C. frutescens* in shape. It bore very few fruits and these fruits produced far fewer seeds than was normal for either species. The plant had highly reduced pollen stainability (14%). From the 10 mature fruit

collected 21 seeds were harvested, and these were planted the following year at Indiana University. Twenty seeds germinated, and two of the seedlings died. The remaining 18 plants flowered and showed plant to plant variation in characters that separate the two species, such as number of peduncles; corolla color, size and shape; shape and size of the fruit; as well as in fertility. Pollen stainability ranged from 4 to 79% with a mean of 44%. Eight plants produced an abundance of fruit, seven plants produced very few fruits, and three failed to produce fruit. Moreover, it was found that the plants showed various degrees of abnormal leaves or a "virus-like syndrome," similar to the condition described by Pickersgill (Evolution 25:687, 1971.) in F_1 hybrids involving other species. The morphological similarity of 7105 to artificial hybrids of *C. annuum* var. *minimum* x *C. frutescens* and the morphological variability and sterility found in its progeny (either selfs or backcrosses) strongly indicate that the plant is a hybrid. Possibly the other deviant plant of *C. annuum* var. *minimum* in the original population is a hybrid derivative. Specimens of 7105 and its progeny are deposited in the herbarium of Indiana University. Only one natural hybrid was reported previously between *C. annuum* var. *minimum* and *C. frutescens* (Heiser, Ciencia y Naturaleza 2:53, 1964.) Perhaps hybrids between the two are not uncommon as they may often grow together as weeds. Some of the variation in the two species, particularly in fruit shape, may result from introgression, but it is likely that the self-pollinating habit as well as sterility limits the amount of gene exchange between the two.

Uses of Computerized Floristic Data of Indiana for Plant Geography¹

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Abstract

The work reported here is an attempt to demonstrate how computers can make data available in floras of more value to plant geography. Deam's *Flora Of Indiana* was used to extract county distribution data on the 81 taxa of the Brassicaceae growing in the State. These data were used to generate county by county checklists, summary statistics of the number of species per county, and two indices of similarity among all pairs of counties. The results of the similarity studies were depicted as geographic contour maps, with each isopleth a level of similarity; as a phenogram; and as a computer generated geographic map of the State in which counties with high similarity with each other are differentially shaded with the same symbols. The pattern revealed clusters of counties that corresponded with known environmental characters in north-south or east west gradients. Four counties appeared unexpectedly dissimilar from others. This seems explainable either by inordinate amounts of collecting there, or by the association (of two) of the counties with prairie communities of Illinois. Computerized analysis of floristic data has potential to permit further insights into the phenomena of plant geography.

In the 33 years since the publication of Deam's (2) *Flora Of Indiana*, systematic biology has experienced an increase of research activity. It has incorporated new kinds of data into its store of information. These include chemosystematic data and research using the scanning electron microscope. Of equal importance is the use of computers to serve as an efficient means to store and to retrieve desired aspects of these voluminous data. In the few years that have elapsed since the beginning of the use of computers for biological information retrieval, we already realize that the accumulation of reliable data is essential to sound progress in plant systematics. For this reason we were anxious to explore ways to unlock those data in printed floras that are the result of diligent, professional, floristic studies.

The purpose of the present work was to analyze a part of Deam's *Flora* to demonstrate its additional value to plant geography and ecology. While the data have been available since 1940, we had to wait for the computer as the medium through which we could rearrange and analyze it efficiently. Specifically, we concentrated on the data available for the geographic distribution of each species of one family in the State.

Materials and Methods

The materials used were the county distribution maps of the 81 species and varieties of the Brassicaceae (mustard family) recorded by Deam as growing in Indiana, both native and introduced. For this

¹ This project was supported partially by National Science Foundation, Office of Science Information Services, Grant GN-878, to Theodore J. Crovello.

preliminary study no attempt was made to update the distribution maps of Deam with later collections. Our resources did not permit this. The Brassicaceae was chosen because it is the family of greatest interest to the authors and because it contains both native and weedy taxa in Indiana.

Data from each map were accumulated on computer punch cards. These included the coded species name and counties in which Deam had recorded its occurrence. To facilitate data capture, a transparent "mask" containing county identification numbers was placed over each map. The number of each county in which the taxon was collected was then recorded. The data on the cards were then verified for correctness.

Data analysis was accomplished using our own computer programs written in the PLI language. Phenograms, designed to depict the similarity among all 92 counties simultaneously, were calculated using NTSYS, a set of programs developed by F. J. Rohlf and R. R. Sokal. All computations were made on Notre Dame's IBM 370/158 digital computer.

Readers can get a deeper insight into our methods by a brief statement of what each computer program does. For simplicity we name each program in capital letters.

INDIANA 1 takes the distribution data from cards, arranges them in a species by county table, and stores them on magnetic tape for later, efficient use.

INDIANA 2 uses the above data table to produce an outline map with the number of species per county.

INDIANA 3 uses county data to produce an Indiana map wherein each county is shaded (by computer) to represent different values (*e.g.*, number of species per county, or the value of some biogeographic diversity index for each county).

CHECKLIST uses the data of INDIANA 1 to produce county checklists of species recorded from the county. Conversely, it can produce checklists by taxa. Either scientific or common names can be requested.

HUHEEY also uses the data of INDIANA 1 to calculate an average divergence value of each county with each of its neighbors. As given by Huheey (4), the divergence value of counties *a* and *b*, $D_{a,b}$ is:

$$D_{a,b} = \frac{N_a + N_b}{N_a + N_b + N_c}$$

where N_a is the number of species in county *a* but not in county *b*, and N_b is the converse. N_c is the number of species common to both counties. Hence, if two counties are identical, their *D* value will be 0.0. If they are absolutely *different* ($N_c = 0$), then their *D* value will be 1.0.

The numerical taxonomy programs of Rohlf and Sokal, NTSYS, were used to calculate the simple matching coefficient between all pairs of counties, and to create a phenogram using the Unweighted Pair Group Method. Consult Sneath and Sokal (7) for computational details.

Results

It required 1 hour to extract and keypunch the distribution data from five of Deam's maps. Recent changes in procedure allow us now to capture data on 20 maps per hour. To conserve space, we shall not present those results which the reader can visualize easily.

Figure 1, a result of INDIANA 2, is an actual computer printout of a county outline-map of Indiana which contains the number of species of the Brassicaceae collected in each county. Such maps are useful to discover readily which parts of the state have a rich flora for this family. They also can be used to ascertain which counties might be poorly collected to date. For example, Fayette and Union Counties surely have more than one and two species, respectively. The computing cost to calculate such statistics and to print the summary map was under \$5.00. Actual computer time was **20 seconds**. Similar costs cover the production of shaded county maps by the INDIANA 3 program.

CHECKLIST'S results are simply the inverted files of the basic species by county table. The cost to produce a county checklist for all of the 92 counties of Indiana was \$3.00. This also included a second list, one species at a time, of which counties from which it had been recorded.

Another form of output is a base map of Indiana to which has been added the value of Huheey's Divergence Value for each county. Recall that a county absolutely similar with all of its contiguous counties would have a value of 0.0 (no divergence). A county that had no species in common with any of its neighboring counties would have a value of 1.00 (complete divergence). No county has a divergence value lower than 0.6, indicating that a considerable degree of dissimilarity exists among all counties. The greatest divergence values, hence the most likely area for a biogeographic boundary, occur roughly from east to west in the central part of the State. Another transect of high divergence is present in the southwest quarter of the State, running from south to north, before turning westward.

Figure 2 summarizes the relationships between the counties using the simple matching coefficient. It is a summary of the relationships obtained using NTSYS and its resulting phenogram. Since there are so many counties, it is impossible to present the detailed phenogram here. We believe that this is the first time that the results of a phenogram have been summarized by the differential shading of a geographic map. Computing cost to produce these results was under \$5.00.

Figure 3 summarizes relationships among the counties according to Huheey's Divergence Index. The Index for each county appears by the county name, rounded off to the nearest tenth of a unit. To indicate directions and rates of change in the State, isopleth lines of equal Divergence Values were fitted and drawn on the printout by eye.

Discussion

Given the results of analyses like those described above, additional biological insights are provided by attempts to correlate environmental

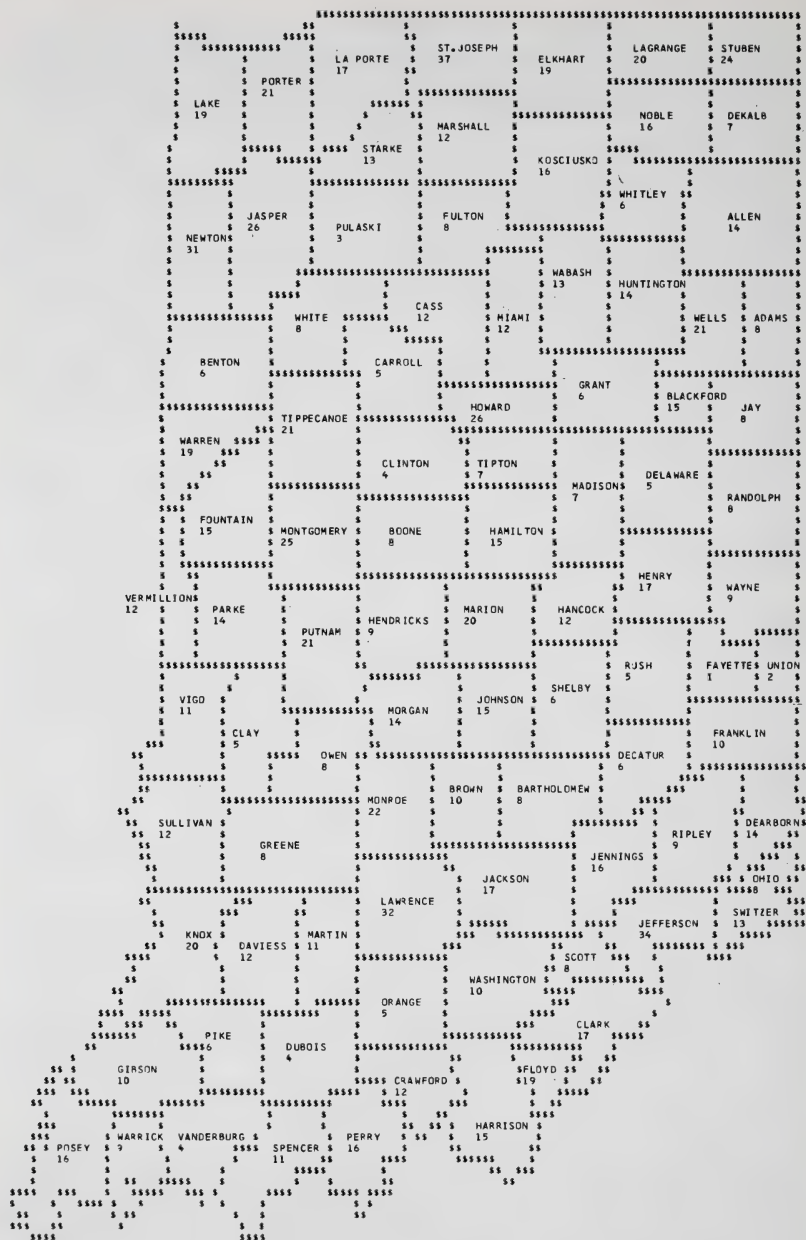




FIGURE 2. Computer printout of the State of Indiana showing the relative similarity among counties as determined by numerical taxonomy. Counties shaded with the same symbol are more similar in the species that grow there than they are with counties shaded otherwise.

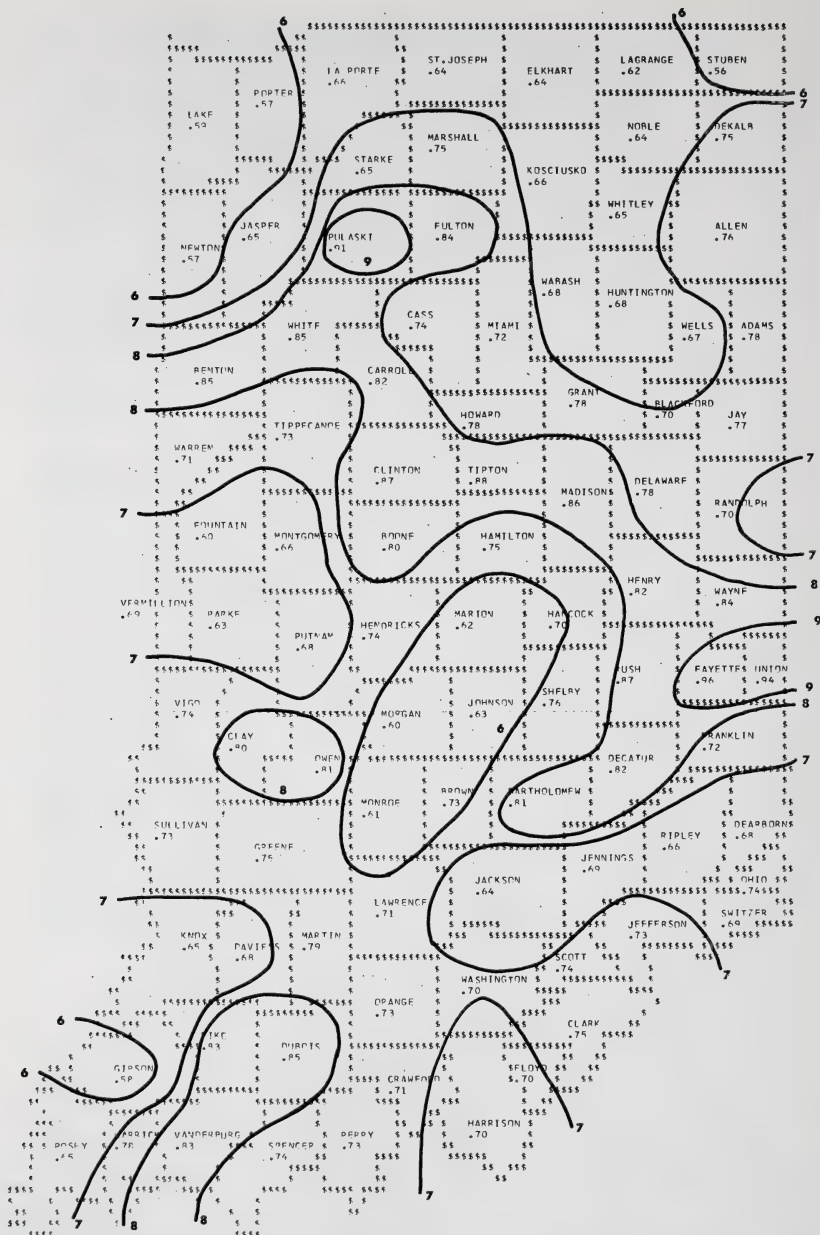


FIGURE 3. Computer printout of the State of Indiana showing relationships among counties according to Huheey's Divergence Value. Isopleth lines of equal Divergence Values were fitted later by eye.

data with the distribution pattern of one taxon at a time (using each map in Deam separately), or with the average distribution of a larger taxon (here the 81 species of the Brassicaceae). This can be done with transparent overlays (as in 1, 6), or it can be done via computer. We know of no other phytogeographic study which has calculated average phytogeographic similarities among geographic units. Zoogeographic workers such as Fisher (3) and Huheey (4) have made such analyses, however.

Figure 2 visually seems to be correlated with several climatic and geological characters. For example, there exist north to south latitudinal gradients on the figure which agree with climatic variables like length of frost free seasons and normal annual precipitation.

Even more interesting is the similarity among a "column" of counties in the southwest part of the state (Figure 2, counties with vertical line symbols; and those counties with the plus symbol). These coincide nicely with bedrock geology. Four counties were found to be very different from the others. Two, Jasper and Newton, are the familiar extension of the Illinois Prairie into northwestern Indiana. The third, St. Joseph County, may be anomalous due to the very intensive collecting by Notre Dame botanists, which extended over several decades. The authors are not familiar with Clark County, the fourth anomaly. But all of the 17 species reported there are very common. Also, it too was quite heavily collected when the Coulter brothers were resident at Hanover.

In this preliminary study readers must be careful not to put too much emphasis on the particulars of our results. Our caution stems from our current ignorance of which of the county-species combinations that are not positive are due to non-occurrence and which are due to incomplete collecting. Yet we can easily visualize the interesting questions that can be answered with such procedures. For example, does each plant family show the same phytogeographic boundaries in the State? If not, why not? Similarly, within a family like the Brassicaceae, do the many introduced weedy taxa show the same patterns as the native taxa? If not, what does this imply? Similar questions could be asked about different ecological succession stages. Such detailed studies await a more complete set of data.

The present study utilized only plant distribution data to demonstrate that the value of floristic data can be enhanced through selected use of the computer. Readers should be aware that such data are only a fraction of that available in a flora. Keller and Crovello (5) indicated how computers might be used to capture and analyze actual descriptions of taxa, including habitat data. These studies have led us to an even deeper conviction that reliable, descriptive taxonomy is essential to further progress in systematics and related fields.

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A Computerized Flora of Indiana: Its Scope, Value and Feasibility¹

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Abstract

The scope, value and feasibility of a Flora Indiana Program is explored, along with the role that electronic computers might play to make the program more valuable and efficient. Deam's *Flora of Indiana* would serve as the foundation on which we would build. The scope of the flora, be it a mere checklist or detailed account of each species (including weeds), will depend on the level of human and monetary resources available. A Flora Indiana Program would provide an updated inventory of the plants of the State which would be of use to many people, not just taxonomists. Direction would be by a committee of interested and capable systematists and others. Official sponsorship might best be given by the Indiana Academy of Sciences. Funding should be sought from sources at different levels of government and from the private sector.

This paper considers several aspects of a Flora Indiana Program. Deam's (2) *Flora of Indiana* provides an excellent foundation for our current needs. Since such a program will require significant amounts of human and monetary resources, we must evaluate it carefully, first to determine its optimal scope and value, and then to ascertain if it is feasible. The technology of electronic computing will also be considered as a means to enhance the value and efficiency of a Flora Indiana Program.

History of Floras

Floristic work dates back to the earliest beginnings of botany in Greece. Theophrastus, a student of Aristotle, classified and described about 480 kinds of plants in his *Historia Plantarum*. But, even today vast areas, especially in the tropics, have not been adequately treated. It is only within the last decade that a Flora of the Soviet Union has been completed. The Flora Europaea Program is still under way with completion scheduled in the next few years. There is no very active program to inventory and to describe adequately the more than 25,000 species of vascular plants that grow in North America north of Mexico. After years of careful planning and of pilot feasibility studies, funding of the Flora North America Program was terminated in 1973 by the federal government.

Floras vary in their content. A flora may be a mere checklist of the species of plants growing in a region. To this can be added a key to determine to which species a new plant belongs, together with flowering dates of each species, the type of environment in which each grow, etc. Deam's *Flora of Indiana* contains keys to the families, genera and species he knew to grow in the area, distribution maps and some habitat information.

¹ Project supported by the National Science foundation, Office of Science Information Service, Grant GN-878.

Recently, several projects have used the speed and efficiency of computers to aid in the production of floras. Most have concerned themselves with the production of distribution maps. These include Perring and Walter's (4) *Illustrated Flora of the British Isles*, and the *Flora Warwickshire* (1). Other botanists have used the computer to summarize the differences in flowering time for each species in various parts of a state (3). The now inactive Flora North America Program would have created a computerized plant data bank containing for each species its common names, key characters, habitat and distribution data.

Scope of a Flora Indiana Program

What species should be included? All should be, but the problem is to determine which ones realistically can be included. For example, fungal parasites causing diseases of trees and of economic or horticultural plants ought to be included. Deam only treated the vascular plants. Given current resources, it would be easiest to build our floristic program on Deam's foundation.

The next step would be to add all additional records of new plant occurrences that have appeared in the literature or have been added to herbarium collections in the State. These would not be added until their identification was verified by a trained taxonomist. Information on agricultural and horticultural plants growing within the State could also be included. A computerized data bank containing vital information on such plants would permit botanists at the State's universities, and agricultural and farm agents, to answer some of the questions that they now cannot answer.

Value of a Flora Indiana Program

A current floristic project, able to retrieve data quickly would be of use to many people. These include plant and animal taxonomists engaged in basic and applied research. They would know what species to expect in an area, when to find them, and in what habitats. They also would know what counties have not been studied well, and what taxa to try to find in each area. Ecologists would profit from the analyses that would provide summaries of distributions by plant families or other categories. For example, if each plant family has a different distribution pattern in the state, this information could be used to pose new questions of evolutionary and ecological importance. Natural resource workers such as wildlife managers, foresters and park rangers might be more interested in only segments of the total flora of the State. For example, a park naturalist may wish a listing and description of only those spring flowering plants that grow in the county in which the park is located. Others may wish a list of species associated with a particular soil type or bedrock geology.

An updated flora, particularly local geographic subsets of it, would be useful to high school teachers desiring to teach their students more about the quality of the plant life immediately about them. Such local or county floras could be produced easily by computer as customized

subsets of an overall State flora. Also, these local floras would have keys to just the species growing in the county. The computer can produce such truncated keys very efficiently, once the large key for the entire flora (such as from Deam) has been captured. Citizens of the State who are members of garden clubs, and other nature groups, would also welcome more localized floras. It should also be useful to physicians in local Poison Control centers at hospitals.

Feasibility of a Flora Indiana Program

To assess the feasibility of such a program requires consideration of several different aspects. These include its organization and governance; the people working on it; its sponsorship; its funding; and its physical housing.

Organization could follow that of the Flora North America Program. It had an Executive Committee consisting of well-known systematists. We also could add State Natural Resource workers, *ex officio*, etc. They voted on major policy issues of the program. To complement them, the State could be divided into geographic regions, each with a regional floristic center. Most often it would be a college or university with a resident taxonomist interested in the program and an herbarium of some size. It would serve as the focal point for all floristic activity in that region, including the search for species that should be in the counties, but have not yet been found. Such activities would be helped by computer printouts of selected data. These regional centers would communicate among themselves and with one central office. This is only one of the possible forms of organization.

The human resource is the most essential for a successful program. The most likely people are the college and university teachers throughout the state with an interest in floristics and plants in general. They themselves may rarely be able to get into the field. But they are in a position to encourage many eager students and to involve high school biology clubs and teachers in the many activities associated with floras. Ways of involving the State's Natural Resource personnel should also be explored, especially if we can demonstrate that the State and its various activities might benefit directly from a Flora Indiana Program.

Sponsorship does not necessarily mean funding. Thus the American Institute of Biological Sciences sponsored Flora North America but did not provide funds. Since individuals are not permanent, some established, not for profit organization should be its sponsor. Among the botanists who discussed this matter, we all concluded that the Indiana Academy of Science is the logical sponsor. Its Plant Taxonomy Section is the logical unit in the Academy to which responsibility for its monitoring should be assigned.

Funding of the Flora Indiana Program may be from one source or from many. The National Science Foundation could be approached, either through its Systematic Biology Program or one of its educational divisions. Similarly, since the flora is an integral and dominant part of the environment, one of the environmental education programs spon-

sored by congressmen, such as Indiana's John Brademas, could be investigated. Possibly some State money would be made available if sufficient value could be demonstrated. Private foundations could also be contacted. Costs need not be astronomical. For example we could generate county checklists for all counties for \$10,000 to \$20,000.

Given the existence of the many herbaria in the State, physical facilities would require little that is not already present. Computing facilities would probably be those that exist at several college campuses. Dissemination of the result could include a printed flora of the State, subsets for a given county, and computer printouts to answer special requests.

Conclusions

Considering the history of floras, the current needs of society, and the possible scope of a Flora Indiana Program it seems to be a valuable project. After discussion of these and other points at the Plant Taxonomy Section of the Indiana Academy of Sciences meeting (October 1973), the following agreed to consider the matter further: Doctors Charles Heiser (Indiana University, Bloomington), Joseph Hennen (Purdue University), Thomas Mertens (Ball State University) and Theodore Crovello, Chairman (University of Notre Dame). Please direct your comments and suggestions to any of the above.

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SCIENCE EDUCATION

Chairman: GERALD H. KROCKOVER, Department of Education,
Purdue University, West Lafayette, Indiana 47907

STANLEY S. SHIMER, Science Teaching Center,
Indiana State University, Terre Haute, Indiana 47809
was elected Chairman for 1974

ABSTRACTS

Teaching Science Creatively in the Elementary School. ALFRED DE VITO, Department of Education, Purdue University, West Lafayette, Indiana 47907.—Creativity is something everyone possesses in varying degrees; everyone is born with some creative potential. Creativity occurs at almost all ages and in all fields of human endeavor. Teachers dubbed “creative” produce new, original, unique learning situations wherein students can create new, original, unique solutions to problems and discover new patterns, new ideas, or new products. Creativity can be developed, and its development depends upon the environment into which it is introduced and circumstances that condition it.

Science teaching in the elementary school and creativity should go hand in hand. Science is a “natural” for creativity. The scientist is one of the most creative persons in our society—frontiers in science are constantly being advanced by his creations.

The qualities or characteristics of scientists are in many ways analogous to those traits associated with the creative individual. Scientists are curious; they have a spirit of adventure and a thirst for investigating discrepant situations; they are independent. Scientists have been classified as risk-takers because they look for that solitary chance that an unmarked avenue of investigation might contribute to the solution of a problem. Scientists are further recognized as individuals with strong imaginations and inventive behaviors.

It is generally accepted that creativity can be developed in students if in the learning process the teacher initiates creative situations to which students can react accordingly.

The Art of Innovation: A Study of the Mechanics of Being Creative. LAWRENCE E. POORMAN, Department of Physics, Indiana State University, Terre Haute, Indiana, 47809, and M. DANIEL SMITH, Department of Education, University of New Hampshire, Durham.—The problem faced by science educators in being creative in innovative ideas is too often a singular effort done under pressure from administrators. This paper deals directly with the experiences gained by the author as a team member in achieving the art of innovation through trial and error mechanics of creation.

Details of the workings of the multi-media systems group at Harvard during the 1960's in connection with Project Physics development was elicited and discussed. The team which eventually found

success consisted of: a child psychologist, a philosopher, a science educator, a progressive teacher, a traditional teacher and a visual aids specialist.

The thesis is: "more than one head is needed to be creatively innovative".

Literature Review: Creationists vs. Evolutionists in California. ROBERT BURTCH, J. B. Nelson Elementary School, Batavia, Illinois 60510.—The literature was searched to develop an understanding of the evolutionist and creationist viewpoints appearing in educational publications. In California about 10 years ago, a controversy which debated whether the creationist view of the origin of life must be presented in science textbooks alongside the evolutionary view was initiated. Legal actions have been threatened by each group. This report traced the history of the controversy from its beginning and identified the positions taken by each group. Because California purchases about 10% of the science textbooks, publishers strive to meet California requirements. Thus, this controversy will affect the contents of most science textbooks.

Teaching Science Through Interest Centers. GERALD H. KROCKOVER, Department of Education, Purdue University, West Lafayette, Indiana 47907.—Interest centers can be used effectively as an adjunct to the ongoing science program. Interest centers can be utilized with the trends to the integrated curriculum, open concept learning, and individualized instruction. They may be divided into three types including: Content Interest Centers, Skill Interest Centers, and Theme Interest Centers.

The following components may be found in an interest center: task cards, media aids, audio-tutorial tapes, science book kits, skillettes, buzz boxes, games, field trips, invitations to investigate, and puzzler activities. Interest centers can bring the science teaching of the future into your classroom today.

Solar System: An Educational Play. JAMES M. SMITH, Box 23, Liberty, Indiana 47353.—A play is used to teach astronomy, at the same time children gain acting experience. Directed toward children 10 to 14, this play can best be done on tennis court, lawn, or basketball court. Actors dress as a Greek god for each planet and go to orbit as directed by Sun. The timing is 1 second of play to one day of planet motion—thus earth would move around sun in 365 seconds. Each actor tells about himself as a god and as a planet.

A thoughtful teaching method, the writer hopes to film and sell the play so that it may be used as an educational movie as well as a play available to teachers.

A Science Program Designed to Prepare Sixth Graders for ISCS. JANE A. RHOADES, Kirby School, Tinley Park, Illinois 60477.—The purpose of this program is one in which the task of the teacher is to assist the student in making a transition from a traditional text to working entirely on his own in the ISCS Science Program. The child must learn

how to take on responsibility and complete his work by budgeting his time. Thus, the program was designed so the child learns by doing by the inquiry method.

A brief lecture is given by the teacher to the child on the day's work and then the child begins his activities. Both the Life Sciences and Physical Sciences are emphasized through general topics of observation and communication. Topics covered include animals, hamsters, gerbils, and mealworms, plants, sight-microscopes, bacteria and molds, kitchen physics, electricity, and simple machines. The students are made conscious of the scientific method and how to approach a problem as well as developing their own experiments.

The course was designed to use several sources and to allow the students to participate in several activities. The various units were based on units from SCIS, ESS, AAAS, and NSTA materials which were modified to adapt to the situation and in some instances to allow a one-week presentation.

The metric system was introduced by using the Cuisenaire Rods, math rods, and various activities using graph paper and meter sticks. This is a very important part of the program as the students next year will be doing physical science and measuring entirely in the metric system.

Commitment to Science in Elementary Schools: A Survey Report.

CHARLOTTE M. BOENER, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.—The State of Indiana Science Advisory Committee is attempting to develop a more definitive statement of its recommendations for the inclusion of science in the elementary school curriculum. At the committee's request and with the cooperation of the Senior Science Consultant in the Department of Public Instruction, a letter was sent to all members of the Council of State Science Supervisors and to the science consultants in many of the larger school corporations in the United States. Responses were received from 26 states (including the Canal Zone and the District of Columbia) and 7 large school systems. Some systems responded by sending copies of their science curriculum, some indicated the extent of their commitment by quoting positive statements published in general curriculum reports and others noted that there was no definite commitment for science learning activities in the elementary school curriculum. The results of this survey indicate the need for additional efforts to incorporate science as an integral part of each elementary school child's educational program.

Pictures of Scientists as Drawn by Children and Their Concept of Science.

KENNETH W. UHLHORN, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.—When science educators attempt to discover the concept elementary school age children have of science, they are faced with many problems. The major problem is the inability of primary and some intermediate children to express themselves verbally.

This study is based on a survey of the drawings of a scientist made by more than 3,000 elementary school children from Indiana and

Illinois. The drawings were made by students of in-service teachers who were enrolled in extension classes taught by the author at eight different extension centers of Indiana State University.

Each picture was analyzed to see which of 35 selected characteristics of science and scientists had been included in the drawing by the elementary school child.

The technique used in this study has many possibilities in investigating children's concept of science and scientists. It is a non-verbal technique which can be used successfully in the primary grades as well as in the intermediate grades. The potential of this mode of investigation is one which science educators should not overlook.

An Experimental Program in Physical Science for Prospective Elementary Education Majors. VAN E. NEIE, Departments of Physics and Education, Purdue University, West Lafayette, Indiana 47907.—As part of a 3-year UPSTEP grant to Purdue University, an experimental program in physical science for elementary education majors has been implemented. This two-semester course is a laboratory-based, inquiry-centered set of experiences that follow a carefully planned story line with a limited number of basic concepts "recycled" in new and repeated contexts. The program utilizes portions of *College Introductory Physical Science* and *The Project Physics Course* in developing the unifying theme "Man and His Environment." The main emphasis is on the understanding of a few basic ideas rather than "coverage" of a lot of meaningless jargon to be forgotten at the end of the experience. The many activities that the students participate in are related to prior and ongoing experiences in the elementary school classroom.

Two Multidiscipline Sciences Degree Programs: A Survey Report. CHARLOTTE M. BOENER, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.—One of the factors which affect curriculum changes in universities and colleges is the requests from students. Recently at Indiana State University there have been requests for liberal arts degree programs in Sciences and in Environmental Education. In an effort to assess the extent to which other nearby universities and colleges meet these needs, a letter was sent to 119 colleges and universities in Indiana and surrounding states soliciting information about teaching and non-teaching degree programs in these two areas. Seventy-nine schools responded. The results of this survey clearly indicate that, except for the general science teaching degree, these multidiscipline science programs are not regularly offered.

The Use of Individualized Media for Selected Environmental Topics with the Prospective Elementary Teacher. ROBERT K. CAUDELL, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.—The development of carrel packets dealing with environmental topics is an innovative component of our elementary science methods course.

These learning packets will become an integral part of the open laboratory approach, utilized in the course. Students may independently

use the learning packet which consists of synchronized tapes and slides in a self-contained audio-projection unit.

One packet that has been developed provides an informational overview of the pond as a community. In this instance, the student may independently learn the important biophysical factors as well as the dominant organisms that interact in a small and relatively closed aquatic ecosystem. The instructor may choose this packet as an introductory lesson, as an implementation to the onsite field trip, or as a follow-up activity concluding the field study. In addition to the basic conceptual information, instructional techniques are woven into the program to help relate facts and concepts to possible instructional methodology.

An Experimental Environmental Science Program for Undergraduates. MARSHALL E. PARKS, Science Teaching Center, Indiana State University, Terre Haute, Indiana 47809.—*University Studies* is an experimental, general education curriculum offered to selected students at Indiana State University. This curriculum was developed to stimulate innovative teaching approaches in all fields of study.

One of the science courses, "Man and His Environment," is designed to provide the students with an opportunity to analyze selected environmental biophysical interrelationships and man's influence on them.

Early in the course, the students are trained to use recognized qualitative and quantitative techniques to study and interpret three diverse types of habitats. To culminate this phase of instruction, each student is challenged to design a study and to solve a problem concerning the plankton population density in a pond.

In another portion of the course, each student identifies an environmental problem of interest to him and conducts an extensive investigation of this problem. The results of the student's research are presented orally to his classmates and reported in a paper to the instructor at the termination of the course.

Throughout the course, class seminars and debates focus on important and often controversial environmental issues; in these discussions, both pro and con views are presented by panels of students. The debates are videotaped for subsequent analysis and discussion.

The major purpose of this course is the development of appropriate attitudes and strategies of inquiry that will help the student become an environmentally literate citizen that can and *will* intelligently manage his environment for himself and future generations. The study of the real environment and the discussion of environmental issues help to accomplish this goal.

Teaching Good Optics Through the Physics of Photography—A Mini-course for a Variety of Purposes. VAN E. NEIE, Departments of Physics and Education, Purdue University, West Lafayette, Indiana 47907.—A series of 12 minicourses has been implemented at Purdue University for the purpose of offering a variety of physics courses to the non-

science major. One of these is *The Physics of Photography*, a 5-week unit on basic optics as related to photographic systems. This offering is easily adaptable to many kinds of administrative arrangements at both the secondary and college levels. Within these courses the basic concepts are treated in an intellectually honest way, but with the added motivation of relevance to a popular topic.

NOTES

Relationships Between Concrete and Formal Operational Science Subject Matter and the Intellectual Level of the Learner. ANTON ERIC LAWSON, Department of Biological Sciences, Purdue University, West Lafayette, Indiana 47907.—This investigation was conducted to find answers to the following questions: 1) What are the levels of intellectual development of selected biology, chemistry, and physics students as determined by Piagetian tasks? 2) What are the major concrete and formal operational concepts taught those students? 3) Are concrete operational students able to understand only concrete concepts while formal students are able to understand both concrete and formal concepts?

Procedure

Subjects were selected from biology, chemistry, and physics classes at Norman High School, Norman, Oklahoma. They had been taught the normal subject matter by the classroom instructor. During the last month of instruction in the 1972-1973 academic year, 51 biology students, 54 chemistry students, and 33 physics students were interviewed with four Piagetian tasks: Conservation of Weight, Conservation of Volume, Separation of Variables, and Equilibrium in the Balance. Two written problems to assess developmental levels were also administered to groups of students. Comprehensive examinations were constructed which consisted of approximately 15 items to assess understanding of concrete concepts and 15 items to assess understanding of formal concepts. These examinations were face validated by five qualified science educators and administered by the classroom instructors.

Results

On the basis of the Piagetian tasks, 64.8% of the biology sample was categorized as fully or partially concrete operational. The chemistry sample was best characterized as transitional thinkers with 92% categorized above concrete operational and below fully formal operational. The physics sample also consisted largely of students operating somewhere above fully concrete and below fully formal operational.

Obtained subject matter examination scores, which were corrected for chance success, indicated that subjects categorized as concrete operational demonstrated understanding of some concrete concepts, however, demonstrated no understanding of formal concepts. Subjects categorized as transitional to formal operational or above demonstrated understanding of some concrete and some formal concepts. These sub-

jects scored significantly higher ($p < 0.01$) than concrete operational subjects on both concrete and formal concept items.

Multiple correlation coefficients between the Piagetian task scores and the concrete and formal concept scores were significant ($p < 0.05$) for each sample.

Step-wise semi-partial regression analysis of Piagetian task scores indicated the Conservation of Volume and Separation of Variables to be the best predictors of success on the concept examinations. Additional predictor variables were not significant in increasing predictive power.

Principal components analysis of the six Piagetian styled tasks indicated high first component loadings (0.69-0.85) for all tasks.

Conclusions

These results indicate that a substantial portion of secondary school science subject matter is not appropriate in terms of the intellectual level of the learner. A significant portion of the students are still operating largely on a concrete level while science content is largely abstract or formal.

Faculty-course Evaluation: An Effort in Mutual Communication. DANIEL W. BALL, Department of Biology, Ball State University, Muncie, Indiana 47306.—One promising avenue of research focuses on course evaluation by students. College students are challenging and questioning many of the traditional classroom teaching methods used in our colleges and universities. Such student efforts have not gone unnoticed in academic circles. According to the Bureau of Institutional Research at the University of Minnesota, more than 5,000 articles have been written on the subject of student-course evaluation since 1945 (1). A sample of these articles reveals one consistent finding: There are data which will support or refute hypotheses regarding validity and reliability of student evaluation of teaching (2).

The purpose of this report is to describe what the Department of Biology at Ball State University is doing in this area. Seeking to improve and enhance a quality instructional program, the Department of Biology embarked on an effort to incorporate student evaluation as one valuable input in course improvement. This effort is predicated on the assumption that students are at least partially capable of distinguishing certain qualities of instruction which increase their knowledge, skills or motivation. The fruits of this effort culminated into an instrument which, during its construction, was affected by numerous "limiting factors" such as:

- 1) How can an instrument be designed for effective use in a multitude and variety of course offerings of the department?
- 2) What student demographic data are essential? Do grade points of students affect how they evaluate? Do males evaluate differently than females? How can an instructor get this information and still insure anonymity?
- 3) On what characteristics of instructors do instructors want feedback? What characteristics of courses and instructors indicate quality instruction?

- 4) What demographic information about individual instructors would be valuable? Is professorial rank important? Years of experience? Class size? Time of day course is taught? Sex of instructor?
- 5) What type(s) of rating scales would provide usable information for the instructor?

The ad hoc committee assigned to this task of building the instrument collected numerous instruments used by other institutions across the country to glean possible answers to these questions. Of particular importance were the *Faculty Characteristics Questionnaire* (3) of the University of California at Berkeley and the *Instructor Rating Scale* (4) of the University of Northern Colorado. In addition, numerous individual faculty members and departments at Ball State University provided their personally designed instruments for perusal. The literature on student evaluation also provided constructive insight in assembling a workable model for this department. The *Rev. Educ. Res.*, Dec., 1971, Vol. 41, No. 5, researches this topic of evaluation and provides excellent reviews and bibliographies.

A working copy of this instrument was piloted Winter Quarter, 1973, for the purpose of allowing individual faculty members input into the final edition. After many compromises, revisions and modifications, the instrument was borne.

An important feature incorporated in this instrument is the three-part organizational pattern—the *Course*, the *Instructor* and the *Student*. In addition to having the course and instructor evaluated by the students, why not have the students evaluate themselves? Having students reflect on their efforts and values relative to the course permits the instructor to place each evaluation in proper context and perspective.

Future plans are indefinite with regard to obtaining statistical reliability and validity of this instrument. The primary goal at present is to help instructors improve their teaching. The Department of Biology is seeking to broaden mutual communication between and among students and faculty by sharing ideas and sentiments. The more information a teacher possesses about the interests, backgrounds, experiences and values of his students, the better equipped that teacher will be to adapt to those needs.

Consideration is being given to conducting these types of evaluations at mid-quarter and the beginning of the quarter to enable instructors to incorporate student ideas during the sequence of the course rather than after the fact. This would involve students psychologically and structurally in the teaching process.

This instrument¹ should provide insight for others contemplating or implementing student evaluations. The uniqueness of each student body, faculty and curriculum inevitably will dictate unique instruments of assessment. As student bodies, faculty and curriculum change so should the instruments of their assessment. The Biology faculty at Ball

¹ Single copies of this instrument are available from the author upon request.

State University recognizes these and encourages anyone embarked on such an endeavor to do likewise.

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A Comparative Study of Compulsory vs. Non-Compulsory Attendance in Secondary Biology Using the Systems Approach to Biology Program as the Method of Teaching. CURTIS L. SMILEY, Department of Education, Purdue University, West Lafayette, Indiana 47907.—Hypotheses were formulated to examine the basic question: Is it essential that secondary students be required to attend daily classes while studying beginning biology using the "Systems Approach to Biology" program as the method of instruction?

Traditionally, due to the Carnegie Unit, secondary schools have a built-in design for compulsory daily attendance. Even with the incorporation of flexible modular scheduling, which has reduced student attendance to two or three blocks of time per week, compulsory attendance is still the practice.

Many studies have been conducted on the effects of individualized instruction; however, little has been researched on non-compulsory attendance. With the advent of the audio-tutorial (A-T) method of teaching, it has been possible to design a schedule which allows secondary students the freedom to attend class as they wish.

Students receive greater freedom as education becomes increasingly more student-centered. Individualized instruction demands less classroom group structuring by placing more responsibility upon the student to plan his daily work.

The following hypotheses were explored in this study:

- 1) There is no significant difference between compulsory and non-compulsory attendance in student attitudes toward the audio-tutorial method of teaching.
- 2) There is no significant difference between compulsory and non-compulsory attendance in 13 types of classroom performances.
- 3) There is no significant difference between students' performance on questions of knowledge, understanding, and application levels when comparing compulsory and non-compulsory classroom attendance ordered according to high and low ability.
- 4) There is no significant difference between pre-test and post-test performances as measured by the Nelson Biology Test for compulsory and non-compulsory attendance students ordered according to high and low ability.

No significant difference was found between compulsory and non-compulsory attendance students in their attitudes toward the audio-

tutorial method of teaching. Neither was any significant difference found between the two groups for any of the 13 classroom performance variables studied. No significant difference was found between compulsory and non-compulsory attendance students subdivided into high and low ability groups in the scoring of knowledge, understanding and application questions on the pre-test and post-test measure. Finally, no significant difference was found in the gain from pre-test to post-test performance between high and low ability students whether or not required to attend daily class.

In general, the data support the contention that, using the *Systems Approach to Biology* program, students not required to attend daily class will perform as well as students who are required to attend daily class in a beginning secondary biology course.

It is recommended that this type of study be conducted in schools with students of different ability level than was used in this research. It is also recommended that this type of study be repeated with students who are on a flexible modular schedule. A final recommendation was made to compare the effects of the amount of time spent on the various student activities designed for the systems approach for the students required to attend class and those not required to attend class.

OTHER PAPERS READ

The Relationship of Prospective Elementary Teachers' Attitudes About Teaching Science as a Process to Their Science Teaching Planning Practices. HAROLD H. JAUS, Department of Education, Purdue University, West Lafayette, Indiana 47907.

Learning Experiences Designed for the Classroom Teacher in an Environmental Education Course. JOHN C. MOODY, Department of Education, Indiana University Southeast, New Albany, Indiana 47150.

A Microteaching Field Experience for Student Teachers. MARSHALL D. MALCOLM, Department of Education, Purdue University, West Lafayette, Indiana 47907.

Science Education in the Indianapolis Public Schools. GARY HUFFMAN, Indianapolis Public Schools, Indianapolis, Indiana 46200.

Science Teaching and Teacher Verbalization

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Abstract

Certain verbal utterances in the classroom by teachers prompt peculiar internalization by students. The result is appropriate if the utterances are precise. If they are not, the internalization is such that incorrect learning results. This paper identifies verbal utterances which can produce an incorrect internalization of learning. These utterances are classified as specific (meaning correct, usage wrong), non-specific (meaning and usage incorrect) and incorrect (correct in context, meaning incorrect).

Introduction

Why do we as teachers of the various areas of science compromise the very principles which we so diligently strive to impart to our students? Within our classroom the stress on scientific methodology as the correct procedure by which truth is processed is without question. Yet our verbal utterances sometimes belie this assumption.

The learning process is evaluated by us as being a desirable or an undesirable response pattern depending on the behavior exhibited by the student. This evaluation which consists of different approaches (direct oral questioning, testing procedures, homework, etc.) prompts us to conclude whether or not the response pattern is a logical consequence of our training objectives. If the response pattern does not fit well with our objectives we further conclude that proper learning did not occur. However, this does not mean that some learning is not manifested. To the contrary, learning has taken place and in some cases retention is prolonged.

Although the actual process of learning is unknown, it is accepted that learning requires the manipulation of symbols. Learning stems from thinking which results from the process of conceptualization and internalization of a peculiar response pattern. Rothkopf (1) describes thinking as a series of mathemagenic¹ behaviors. These behaviors include:

- 1) Translation: where written or spoken symbols are transformed into an internal pattern.
- 2) Segmentation: where the internal pattern is separated according to intonation and rhythmic organization.
- 3) Echoic responses: where segmentation is influenced and modified or augmented by other associations previously internalized.
- 4) Mnemotechnic devices: the incorporating of various methods or devices to improve retention.

If Rothkopf is correct "echoic responses" should command our attention. If problem-solving procedure requires input from the environmental

¹ mathemagenic: mathema (that which is learned), and gignesthai (to be born).

totality of the student's associations, and if these inputs are incorrect the resultant behavior is an undesirable response pattern.

Certain verbalizations by teachers in the classroom situation are manifested in subsequent student behavior. In most cases the situation is compromised and no harm is done. But in some areas of content these verbalizations continue to be made without correction and the student continues to internalize these verbalizations. The resultant response behavior is incorrect and becomes a major factor hindering effective thinking. These verbalizations are classified as specific, non-specific and incorrect statements.

Specific Statements

Specific statements are defined as utterances which can be made without violating proper identification. In other words, it is not the intrinsic meaning which is stated incorrectly but the manner of usage. The usage in the teacher's mind may be rationalized but to the student a specific statement must be translated literally. Echoic responses are thus influenced by this part of the student's internalization process.

An illustration of this utterance type involves the International System of Units (SI) where a meter is stated as being 39.37 inches long. Although used for many years in some industries and in scientific circles SI has not been used by the general public. Since the use of this decimal system of measurement will be introduced into daily activity in the next few years it is imperative that the basic parameters be treated intrinsically rather than by comparison.

The International System of Units should be introduced as a coherent system and not as a comparison to the imperial system. A meter is not 39.37 inches (nor is a yard 0.914 of a meter) and this figure of inches should not be used as a conversion unit. If a conversion unit is used it immediately becomes valid to ascertain the length of the inch. By doing so, the question remains, "how long is a unit of measurement?" The situation has become circular reasoning without instructing or having the student discover the actual parameter of the metric system. The result is a student unable to use SI to maximum effectiveness.

Non-Specific Statements

Non-specific statements are identified as utterances which violate elemental definitions. Not only is the intrinsic meaning of an element stated incorrectly but the manner of usage is also incorrect. It appears that the non-specific statements represent those things used as tools within a particular discipline yet probably were not developed by that discipline. The result is a restriction in the fullest use of that tool.

An example is the concept of the undulating statistical surface mistakenly introduced as the concept of the contour line. The undulating statistical surface is a concept used to describe a three-dimensional surface either real or abstract and is a measurement of volume. The surface is defined by control points having X, Y and Z coordinates. Z

coordinates represent data above a datum at the X, Y location of a control point and may represent: 1) information that can actually occur at a point; 2) information that is derived and can occur at a point (totals); and 3) information that is derived and cannot occur at a point (ratios). Furthermore, the slope length and gradient that occurs between control points is assumed to be constant as the actual surface shape in abstract cases is unknown. The result is an inferred surface symbolized by isolines on a two-dimensional plane which if real could be field-checked but if abstract cannot. The reliability of the surface is dependent upon mathematical procedure and is subject to various bias.

In Earth Science the contour idea is used in "reading" topographic maps and for the understanding of force fields. Developed as a method by which terrain surfaces are "read" and later used in the observation of temperature and other measurements the approach creates variation from the proper use of the undulating surface concept. The undulating surface concept should be developed separately in its own right and with premises intact. It is not exclusively the domain of terrain representation and should not be so presented. The concept must be developed separately as a tool and used with exercises designed to practice its use and heighten understanding.

Incorrect Statements

Incorrect statements are defined as utterances which are correct considering the context in which they are used but intrinsically are incorrect. These utterances outside of their context as used can be seen to be false and contrary to logical thought.

The frequently encountered incorrect statement is "north (on the map) is up." The statement when using a wall map may be considered "correct" but north is not "up" ever. North as a cardinal direction on a map is a relative positioning or direction. If a map is used, north as a direction may be oriented however the map user wishes. Furthermore, if a graticule having curved meridians is used north cannot be considered as having a singular orientation. North arrows are not required with areas on a map that exceed 1° of latitude and longitude in extent as direction is correctly oriented by the geographic grid.

To show this situation consider the necessity of actually pointing toward the north pole. The orientation would be along the chord distance, but in the actual use of a map north is separate from the northerly orientation of the person. North on the map is relative to the map only. A map of the school, village or state drawn on the floor of the classroom and correctly oriented would prevent saying "north is up."

Literature Cited

1. ROTHKOPF, ERNST Z. 1965. Some theoretical and experimental approaches to problems in written instruction. p. 193-221. In JOHN D. KRUMBOLTZ [ed.] *Learning and the educational process*. Rand McNally and Co., Chicago, Ill. 277 p.

Project FUTEPS—A Status Survey of Science Teaching in Indiana

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Abstract

Project FUTEPS is an acronym for "Focus on Useful Teacher Education Programs in Science" which was initiated during Fall, 1972. All science teachers plus seven per cent of the elementary teachers in Indiana public schools were surveyed by a 148 item questionnaire. Seventy-two per cent of the science teachers and 37 per cent of the elementary teachers returned questionnaires. The questionnaire covered personal data, current assignments, experience, training, instructional values, teacher practices, and opinions about support programs. The Indiana Department of Public Instruction, Ball State University, Purdue University, Indiana State University, Indiana University, and Indiana University-Purdue University at Indianapolis shared in developing the questionnaire and processing the data.

Introduction

An Indiana project, "Focus on Useful Teacher Education Programs in Science" (FUTEPS), evolved from a July 1972 meeting of concerned individuals. This meeting, which was held at McCormick's Creek State Park, Spencer, Indiana, was attended by persons representing the science and science education departments from several colleges and universities in the state, staff members from the Department of Public Instruction, science supervisors from the public schools, and representatives from mathematics and the social sciences. The group's desire for specific information about inservice needs of science teachers resulted in the formation of a Steering Committee to launch Project FUTEPS.

Following a September meeting of the Steering Committee, an informal agreement resulted whereby the Indiana Department of Public Instruction was to coordinate the project and develop the data collection instrument; Purdue University was to print and mail the instrument; and Ball State University was to process the data. Indiana University, Indiana State University and Indiana University-Purdue University at Indianapolis provided continued input to the project through the Steering Committee.

Methods

A "Checklist of Science Teaching Practices, Grades K-12", prepared and used in Florida by James V. Pierce (unpublished data), was

used as the starting point for the development of the questionnaire. The committee reviewed this checklist and suggested revisions needed for the Indiana study. A first draft of the questionnaire was circulated among the committee members for additional suggestions. Dr. Wayne Welch, who was on special assignment as an evaluator with the National Science Foundation, was also asked to review the instrument. A second draft was submitted to the Ball State Research Computing Division to mate the desired data with the computer and the questionnaire was then revised to meet data processing requirements.

The final instrument contained 148 items. The first block of questions gathered demographic data. Among these were age, teaching assignment, experience both in the profession and in the teacher's major assignment, courses taken in the various science disciplines, and the currency of these courses.

Two blocks of items were intended to gather information of interest both to the National Science Foundation and to Indiana science educators. One block dealt with the NSF sponsored programs which the teacher had attended. The other examined his experience with the various new science curricula.

Two blocks of questions were intended to gain an overview of teachers' values with respect to science education. One set focused on the purposes for including science in the school curriculum. The second was concerned with the goals of science education (or the abilities that students should carry away from science classes.)

Another block of questions was designed to interrogate the teacher on his familiarity with and use of some 30 teaching strategies and techniques.

The final block of items was directed to teacher rating of the usefulness of some twenty services which might be an aid in performing his job. These services fell into the following categories: those which might be provided by the local district; those which might be provided by the state education agency; those which might be provided by colleges and universities; and those which might accrue from a combination of these sources.

A pilot version of the questionnaire was tested with about 40 teachers during December 1972 and January 1973 to discover problems which might develop during administration of the instrument. The final revision of the questionnaire was printed and mailed by Purdue University in February 1973 and returned to Ball State University during March, April and May 1973.

Data were collected from two populations. The first was the total population of science teachers as reported by their superintendent on the 1972-3 annual EIR-4 professional personnel report. This population included all science teachers in high schools, junior high or middle schools, and departmentalized elementary schools, and other elementary teachers with specialized assignments in science.

The second population was a 7% random sample of all elementary teachers. Elementary teachers were included to explore the applicability

of the instrument and the data collection system to this group. The assumption was made that a random selection of elementary schools would produce a sufficiently randomized sample. The full-time teacher equivalencies reported for the selected schools was totaled and found to be within a fraction of a per cent of 7% of the state total.

The instruments were mailed in packets to the school principal with a cover letter requesting his assistance in distributing and collecting the instruments. Each packet contained a direction sheet, a principal's report form, and an adequate supply of questionnaires to poll the sampled teachers in the building.

A total of 5,492 survey forms were distributed with 3,535 intended for science teachers and 1,930 for elementary teachers. Since 13 teachers were in both populations, there is a discrepancy between the above sum and number distributed. A total of 3,243 forms were returned: 2,545 from science teachers and 700 from the elementary sample. (Four of the returned forms were in both samples.) These figures reveal a 72.0% return for the science teachers. Calculation of the per cent of return for elementary teachers was difficult since the distribution was based on full-time equivalencies; however, on the basis of the number of forms distributed there was a 36.9% return.

A coding scheme was developed to transfer the data into a computer useable form. A sample code and the state numeric school and corporation codes were entered on the questionnaires to simplify the tabulation and retrieval. The forms were checked for omissions and a special code was inserted for missing responses.

The questionnaires were submitted to the Ball State University Computer Center for keypunching. The punched cards were copied onto magnetic tape to facilitate computer processing. Editing runs were made in late July and August 1973, to ensure correct card order for each questionnaire and to eliminate obvious keypunch errors. Due to the numbers involved, no attempt was made to correct other inaccuracies in coding or keypunching; however, the number of errors was apparently small.

The Statistical Package for the Social Sciences (maintained by the Nat. Opinion Res. Cent., Univ. Chicago) was used to process the data. Missing values and values that were out of range for the questionnaire due to keypunch and coding errors were excluded from the statistics. During September and October 1973 several tabulations and cross tabulations were run on the overall file and on various subsets of it using parameters such as sample designation, county, and courses taught.

Preliminary Results

One or more teachers completed a questionnaire from 798 or 81.8% of the 976 schools employing science teachers. Elementary teachers from 56 or 50.0% of the 112 sampled schools returned completed forms.

A brief review of the straight tabulations reveals several initial observations for the science teacher population:

- 1) 55% have not participated in any NSF sponsored teacher education program.
- 2) 45% of the science teachers not currently using one of the new science curricula indicated a desire to use one.
- 3) 33% indicated that they have used but are not now using one of the new science curricula.
- 4) From a list of seven purposes for including science in the school curriculum, science teachers rated the development of science literate citizens, the solving of environmental problems, and the development of wise public decision makers as most important while they rated the production of scientists and meeting of national needs least important.
- 5) From a list of 10 goals for science instruction 7 out of 10 teachers judged that the ability to use the methods and attitudes of science in solving every day problems was one of the three most important goals in teaching science; and 6 out of 10 judged that the ability to apply facts and principles to practical problems had equal importance.
- 6) 36% of the science teachers judged that following the content and sequence of the textbook was useless.
- 7) 39% indicated they used objectives stated in behavioral terms with confidence, 42% indicated they would like help with using them and 19% considered them useless.
- 8) 53% made some use of the Indiana State Science Guidelines.
- 9) 78% permitted students to conduct activities not included in the science text.
- 10) 42% considered that non-graded materials were useless, 36% felt similarly about self-pacing materials, and 49% judged learning contracts to be useless.
- 11) 60% judged that allowing the student to select his own units of study was useless; 56% felt that allowing students to help plan the program was useless and 68% judged allowing students to design their own program of study was useless.
- 12) More than 2/3 of the science teachers indicated they would like inservice programs to aid them in implementing new curriculum materials and to help them with up-to-date methodology.
- 13) 81% felt quite strongly that their materials and equipment were inadequate.
- 14) Two-thirds indicated they wanted to be able to use science curriculum materials on an exploratory loan basis.
- 15) 66% judged that they felt a strong need for local K-12 coordination of the science curriculum.

Although the above list does not exhaust observations that can be made from the initial print out of the data, it includes highlights.

Two additional studies have been conducted which illustrate other categories of information that can be obtained from the file. In preparing a proposal for an NSF Instructional Improvement Implementation Program, the Ball State University Biology Department had the responses to selected items tabulated for biology teachers from a 26-county area surrounding Muncie, Indiana. The Department of Public Instruction requested a cross tabulation of age, total experience, and experience in major assignment, with major assignments. This study was conducted to determine the distribution of future teacher needs in the various categories of science teacher assignments.

Discussion and Future Implications

To determine reliability of the collected data in depicting the status of science teaching on a state-wide basis, the return was reviewed on a county by county basis. For the science teachers, the range was from 25% to 100%. Although the return varied more than 10% from the 72% state-wide mean in 54 counties, 33 of these are

predominantly rural with less than 20 science teachers. Another 17 had less than 50 science teachers where the action or inaction of a single principal could influence the return by more than 10%. Thus, only 4 heavily populated counties were beyond a 10% variation, two of these employed 51 science teachers and one of the others was within 11% of the average.

Although the county by county analysis of the returns would tend to substantiate the validity of almost any state-wide implications drawn from the science teacher data, similar analysis of the elementary returns tended to cast greater doubt on the reliability of this data as a state-wide indicator. Conclusions pertaining to elementary teacher sample cannot be made until these data are subjected to further treatment.

A copy of the straight tabulation of the FUTEPS study has been deposited with each member of the Project's Steering Committee. Science educators are welcome to examine the data. The FUTEPS Steering Committee requires that anyone planning to publish interpretations of the data clear his interpretation with the committee.

Project FUTEPS might be described as a spark that fell into the darkness resulting from an inadequate data base for responsible decision making in teacher education. The data from the project should provide the State of Indiana and its institutions of higher learning with a more solid foundation for building future science education programs. Perhaps just as importantly, the cooperative effort of the Indiana Department of Public Instruction and the several universities has been brought to focus on a common problem—a problem which cannot be resolved by independent action of any single agency.

SOIL AND ATMOSPHERIC SCIENCES

Chairman: WILLIAM R. GOMMEL, Department of Earth Sciences,
Indiana Central College, Indianapolis, Indiana 46227

DARREL W. NELSON, Department of Agronomy,
Purdue University, West Lafayette, Indiana 47907,
was elected Chairman for 1974

ABSTRACTS

Mapping Soil Patterns with Multispectral Data from the Earth Resources Technology Satellite. STEVAN J. KRISTOF and MARION F. BAUMGARDNER, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.—Within the past decade, significant steps have been made in the development of airborne and space-borne sensor systems which gather data by imaging the earth surface in several spectral bands simultaneously. Such data coupled with computer-implemented programs serve as a reservoir for more effective study of the earth's surface.

Our objective was to present the results of analysis of data obtained in 1972 over Lamb County located in the southwestern part of the Panhandle of Texas.

Most of the county is a nearly level to gently undulating plain. Two thirds of the area is irrigated and the other part is rangeland. Cotton and grain sorghum are the main crops. Other crops grown are corn, soybeans, alfalfa, vegetables, and some grasses.

The satellite data were obtained on July 6, 1973 at an altitude of approximately 900 kilometers by a 4-band scanner operated in the spectral wavelength region of 0.5 to 1.0 micrometers. Most of the county is used as a site from which a clustering algorithm is ordered to sort the data into 14 separable categories with different spectral responses. Each spectral category is then used to train the computer (LARSYSAA pattern classifier) to perform a classification on the rest of the area of the county.

From the spectral map and statistics obtained by computer, using the ratio between the relative reflectance in the visible portion of the spectrum, the relative reflectance from the reflective near infrared, and also reading the magnitude of spectral responses, it was possible to identify spectral categories with the features on the ground. Soil patterns, sands and outcrop formations have been delineated between ratio values of 1.15 to 1.40; and vegetation between 0.50 to 1.10 ratio values.

Tivoli-Brownfield fine sandy soils move through the county from west to east. They are light colored sandy soils. They show much higher spectral response than the Amarillo-Olton loamy soil on the north or the Amarillo-Portales loams on the south. The Amarillo-Olton

soil association also differs spectrally from the Amarillo-Portales association which are calcareous and lighter in color than the Amarillo-Olton association.

During the time the data were collected, the studied area was covered with vegetation. However, our results show that it is possible to separate spectrally major soil associations over large geographic areas.

Growth Results of Black Walnut (*Juglans nigra*) Seedlings of Different Seed Sources on Soils of East-Central and Southeastern Indiana 1967-1972. D. R. HENDRICKS and D. O. WATERS, Hayes Regional Arboretum, Richmond, Indiana 47374.—In 1967 and 1968, black walnut (*Juglans nigra*) seedlings of six different seed sources were planted on eight soil types in east-central and southeastern Indiana. The purpose of this planting was to determine the optimum conditions needed to grow black walnut for veneer. Measurements of heights and diameters of these trees were kept for each successive year and computerized. These measurements were tested for significance at a 0.05 level to determine differences in growth of: 1) different seed sources on the same soil types; and 2) each seed source in different soil types.

Five-year results from different seed sources on the same soil types indicated little significance between the different seed sources. Results from different soil types with the same seed source showed that Eel silt loam gave the best growth on 50% of the sites. There was little significance after 5 years between Cincinnati, Fox, Miami, Sloan, Rossmoyne, Russell and Westland.

Studies for next year will combine all seed sources on each soil type to give larger sample sizes and include four more soil types.

Effect of Nitrogen and Herbicides on Oat Grain Protein Content. H. W. OHM, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.—Two oat cultivars, 'Stout' (genetically lower-protein) and 'Diana' (genetically higher-protein) were subjected to treatments of nitrogen and sub-toxic levels of simatryne and tenoran. Nitrogen was applied at 0 and 105 pounds per acre. Available N on unfertilized plots was 40 pounds per acre. Each chemical was foliar applied at 0.1 and 0.2 pounds per acre at the late boot and completely headed stages. The experiment was grown at Lafayette, Indiana, in 1972 in a split plot design with three replications where nitrogen levels were the whole unit treatments; varieties, rates of chemicals and stages of application were the sub-unit treatments.

Diana and Stout produced 19.1 and 17.1 per cent protein in their grain, respectively. Application of nitrogen tended to increase yield, per cent protein and protein yield. The two chemicals slightly increased the per cent protein—18.1 per cent without chemicals *vs.* 18.3 per cent with simatryne or tenoran. However, application of the chemicals decreased yield 3.7 per cent resulting in a reduction of protein yield. Simatryne reduced yield and protein yield significantly more than did tenoran. Protein content was similar with both chemical treatments.

Relationship of Soil Fertility Practices to the Nitrate Content of Drainage Water from Indiana Soils.¹ D. W. NELSON and R. K. STIVERS, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.—Water samples were collected from subsurface tile lines draining commercial cropland and from two depths in the profile of soils treated with varying rates of nitrogen fertilizer. The nitrate content of tile drainage water appeared to be directly related to the prevailing soil fertility of the area drained. Although the nitrate concentration was fairly constant throughout the year, the bulk of nitrate-N lost occurred during late winter and spring when tile lines were flowing at maximum rate. Nitrate N in tile drainage water was found to be equivalent of 10 to 15% of the fertilizer N applied to some tile drained soils. The nitrate-N content of drainage water or soil solution of soils moderately fertilized is relatively low (10-15 ppm); however, some nitrate is detected in drainage water from unfertilized or uncultivated soil. The leaching of nitrate was found to promote mobilization of calcium and magnesium and subsequent loss of these basic cations in drainage water.

Determinations of the Atmospheric Electric Conduction Current. C. R. CHURCH and M. D. ABEL, Department of Atmospheric Sciences, Purdue University, West Lafayette, Indiana 47907.—Factors which influence the magnitude of the atmospheric electrical resistance include the elevation of land areas, cloud cover, atmospheric pollution, atmospheric radioactivity, and natural sources of nuclei. Previous estimates of the global atmospheric electrical conduction current have neglected these effects. They are taken into account in the present calculations, which attempt to provide a more accurate determination of the conduction current.

Treating each effect as independent, the global areas affected and the columnar resistances for those areas were calculated. The influence of each effect on the previously given fine weather value of global conduction current were expressed as percentage changes. The elevation of terrain calculation showed a 14 per cent increase in total conduction current. The effects of cloud cover and air pollution showed a 10 per cent and a 4 per cent decrease, respectively. Atmospheric radioactivity and effects such as dust storms and forest fires were estimated to have negligible influence. Considering all the effects together, the net change was substantially zero, so that the previously given value of 1,400 amperes for the global conduction current remains unaltered by these calculations.

Air Temperature Fluctuation Aboard the *Massalia* During the Eclipse of 30 June 1973. WILLIAM R. GOMMEL and RUTH A. GOMMEL, Department of Earth Sciences, Indiana Central College, Indianapolis, Indiana 46227.—Using a Princo sling psychrometer off the Coast of Mauritania a reduction in air temperature of approximately 2.9 degrees Fahrenheit was observed from 15 minutes after first contact (70.5° F at 9 hours

¹ This work was carried out under AES Project 01453.

40 minutes (Greenwich Mean Time)) to the end of totality at third contact (67.6° F at 10 hours 40 min 38 sec GMT). Wet-bulb temperature fell 1.2° F from 67.0° F to 65.8° F during the same hour, and relative humidity increased from 83 per cent to 90 per cent. By the end of the eclipse at fourth contact (12 hours 2 min GMT), the temperature had increased to 72.3° F.

At totality onset (10 hours 35 min 10 sec GMT) the ship was located at $20^{\circ} 2.5'N$, $17^{\circ} 15.7'W$ and headed due south at 11 knots. Sky was clear throughout the eclipse, and horizontal visibilities were approximately 5 miles to starboard (westward) and 3 miles to port (toward the sun) with haze and light dust layers aloft. The surface wind was from 340° (NNW) 12-14 knots which resulted in a relative wind of 1-3 knots. For approximately 1/2 minute before totality, the relative wind increased perceptibly by several knots. Shadow bands (apparently an interference of light phenomenon) appeared to have a wave length near 1 centimeter and moved with a relative speed of 4 meters/second.

H. Tomioka of Ibaraki-ken, Japan, observed a reduction in temperature of 4.7° Centigrade, and R. A. Richards of Guildford, England, noted a reduction of around 10° F. These instruments were located close to ship structural surfaces and probably reflect somewhat the temperature changes of these surfaces. Actual changes in the free air temperature over the ocean should be close to those observed by the author away from such surfaces. Under similar eclipse conditions over inland areas such as Indiana, air temperature fluctuations should be several times larger than those observed over oceans.

OTHER PAPER READ

Fixed Ammonium Content and Ammonium Fixing Capacities of Selected Indiana Soils. G. R. WAGENMAN and DARREL W. NELSON, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.

Classification of Some Dark Colored Northern Indiana Soils¹

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Abstract

The classification of some of the dark colored, well drained, acid outwash soils in Northern Indiana needed clarification. These soils had been classified into the Soil Taxonomy System as Typic Argiudolls. In the previous system they had been classified as Brunizems. These soils have many shale fragments throughout the profile and are strongly to very strongly acid. The laboratory data indicate that they have low base saturation throughout the B horizons and to a depth of at least 1.8 meters and that they should be classified as Ultic Hapludalfs. This classification does not recognize their similarity to Mollisols.

Introduction

There are approximately 227,000 acres of acid outwash soils containing variable amounts of shale in Lake, Porter, LaPorte and St. Joseph Counties. These soils have been classified in the Tracy, Door and associated series in past soil surveys. About 65,000 acres of these soils developed under prairie or mixed prairie and forest vegetation and the remaining acreage developed under forest vegetation. Carbonates are present below 8 to 10 feet. Soil scientists have observed pyrite crystals in the leached part of some profiles and gypsum crystals in the unleached part.

Shale bedrock formations (Coldwater, Ellsworth and Antrim formations) underlie the drift in this area and in Michigan to the north of this area (1). Shales in the soil mantle are assumed to have been a part of these formations prior to glaciation. Samples from bore holes into the shale bedrock contain an average of 1.4% sulphur (John R. Hill, unpubl. data).

The purpose of the field and laboratory study was to collect information that would help to classify these soils according to the latest soil classification (3). We also wanted to learn why these soils were so much more acid and deeply leached than other soils in the area.

Mollisols are soils that have a thick dark surface horizon high in organic matter and are relatively rich in base saturation throughout the profile ($> 50\%$ by NH_4OAC method to a depth of 1.8 m) (3). Alfisols are usually relatively low in organic matter, have a subsurface horizon with an accumulation of silicate clays (argillic horizon), and have a relatively high base saturation ($> 35\%$ by sum of cations at a depth of

¹ Journal Paper No. 5324. Purdue University Agricultural Experiment Station.

about 1.8 m). Ultisols are similar to Alfisols except Ultisols have a lower base saturation.

Soils that have certain combinations of characteristics are placed in intergrade classes. For example, a well-drained soil with a dark surface layer typical of Mollisols and an argillic horizon typical of Alfisols or Ultisols is an Argiudoll (Mollisol with argillic horizon) if the base saturation is between 50 and 35%; and is a Humic Hapludult (Ultisol high in humus) if the base saturation is less than 35%.

Method

Representative profiles were sampled and described in St. Joseph, LaPorte and Porter Counties. The samples were characterized for physical and chemical properties at the U.S.D.A. Soil Conservation Service Laboratory at Beltsville, Maryland. Standard laboratory procedures were used in the determinations. The symbols in the headings of Tables 1 and 2 indicate the particular method used (2).

Tables 1 and 2 give the partial laboratory data of two representative profiles from prairie areas. One of Door loam from Porter County and one of Door silt loam (now Coupee silt loam) from St. Joseph County. Descriptions of the two profiles follow.

The profile from Porter County (Table 1) has an argillic horizon. It has clay films on ped surfaces which indicate clay movement but it does not have the clay increase from the eluvial (A) horizons to the illuvial (B2) horizons that is typical of argillic horizons. The original material of the A horizon contained more clay than that of the B2 horizons and subsequent clay movement was masked by the original material difference. The base saturation by sum of cations at 1.8 m deep is 39%. The weighted average particle size distribution in the control section, 43 to 93 cm in this profile, places the soil in the coarse-loamy class, borderline to fine loamy. The complete classification at the family level is Ultic Hapludalfs, coarse-loamy, mixed, mesic. "Coarse-loamy" is a particle size class; "mixed" is a mineralogy class; and "mesic" is a temperature class.

TABLE 1. *Laboratory data for Door loam, Porter County, Indiana.*

Depth in cm	Horizon	Total % of < 2 mm			Coarse fragments 2-76 mm % of < 76 mm 3B1	pH (1:1) H ₂ O 8C1a	Base Saturation		
		2.0- Sand .05 mm 1B1b	0.05- Silt 0.002 mm 3A1	Clay < .002 mm			Sum Cations 5C3	NH ₄ OAC 5C1	% Organic Carbon 6A1a
0-20	Ap	45.8	33.0	21.2	--	5.6	52	71	2.94
20-33	A1	48.9	31.3	19.8	1	5.8	43	58	2.57
33-43	A3	55.1	26.7	18.2	9	5.5	30	50	1.60
43-61	B21t	58.7	23.8	17.6	12	5.5	24	40	0.81
61-79	B22t	62.1	19.9	18.0	19	5.4	28	43	0.43
79-99	B23t	67.8	16.6	15.6	18	5.4	28	45	0.42
99-129	B24t	60.3	19.3	20.4	26	5.2	25	41	0.24
129-167	B31	53.9	21.2	25.0	44	5.3	39	62	0.51
167-200	B32	66.1	14.1	19.7	33	5.7	39	69	0.44
200-225	IIC	89.9	4.8	5.3	5	5.8	28	56	0.14

The profile from St. Joseph County (Table 2) also has an argillic horizon, but the base saturation at 1.8 m deep is 29%, less than the 35% upper limit for Ultisols. Also, the profile has a sharp texture change at about 84 cm and because this change is within the control section, 53 to 103 cm for this profile, the soil is placed in a contrasting-texture family. The complete classification of this profile is Humic Hapludults, fine-loamy over sandy-skeletal, mixed, mesic.

TABLE 2. *Laboratory data for Door (Coupee) silt loam, St. Joseph County, Indiana.*

Depth in cm	Horizon	Total % of < 2 mm			Coarse fragments 2-76 mm % of < 76 mm 3B1	pH (1:1) H ₂ O 8C1a	Base Saturation		
		Sand 2.0- .05 mm 1B1b	Silt 0.05- 0.002 mm 3A1	Clay < .002 mm			Sum Cations 5C3	NH ₄ OAC 5C1	% Organic Carbon 6A1a
0-25	Ap	14.9	58.8	28.3	--	5.8	47	55	3.30
25-36	A1	16.1	58.8	25.9	--	5.6	35	49	2.64
36-53	B1	15.9	60.5	23.6	--	5.3	29	41	1.18
53-66	B21t	36.7	34.9	28.4	1	5.0	38	49	0.65
66-84	B22t	51.5	27.7	20.8	2	5.0	37	46	--
84-92	IIB31	80.1	9.8	10.1	5	5.1	29	35	--
92-112	IIB32	87.7	5.6	6.7	14	5.2	20	28	0.13
112-132	IIB33	90.8	3.6	5.6	18	5.2	23	26	0.12
132-152	IIC1	94.7	2.1	3.2	5	5.3	19	25	0.12
152-183	IIC2	84.1	3.8	9.1	52	5.2	29	38	0.11
183-249	IIC3	91.7	2.0	6.3	7	5.3	43	53	0.25

From other data² representing soils in this area, it is apparent that most of the soils have base saturations more than 35% at the critical depth, so we consider most of the soils to be Alfisols instead of Ultisols. To separate those series in the coarse-loamy family from those in the fine-loamy over sandy or sandy-skeletal family, a new soil series, Coupee, was established to represent the latter family.

If argillic horizons were not present in these soils, they would be Inceptisols. They are borderline to Inceptisols in that the argillic horizons are not moderately or strongly developed. Field observations as recorded in the pedon descriptions shows the presence of clay films to be sufficient for an argillic horizon. Laboratory data (not included in table) shows that the ratio of fine clay to total clay is larger in the illuvial horizon than it is in the eluvial horizon. Ratio of fine clay to total clay in the St. Joseph County profile is: AP — 0.37, B21t — 0.53, and the IIB32 — 0.57. In stratified materials, where the horizons differ in texture originally, it is not expected that there will always be more clay in the argillic horizons than is in the overlying "A" horizons.

In soil classification it is the goal to group soils with the greatest similarity of important properties in the same class. The soils of this study both developed under prairie grasses, as did most Mollisols,

² Laboratory characterization data for Door and related soils (1974) unpublished. On file at Purdue University, Agronomy Department and State Office of the USDA, SCS.

and, except for the lower base saturation in the B horizons, have the characteristics of Mollisols. They are used for intensive crop production as are other Mollisols of the area. In defining Mollisols it was decided, however, that low base status soils should be excluded to maintain homogeneity of base saturation in the Mollisol order. With minor changes in the classification system (3) the similarity of these soils to Mollisols would be recognized (Mollic Hapludalfs instead of Ultic Hapludalfs). This change is under consideration.

Laboratory tests for sulphur showed no sulphur present in the weathered shale in the profile. Since the unweathered shale rock contains about 1.4% sulphur and the shale fragments remaining in the soil contain none, it is assumed that sulphur-containing minerals in the shale weathered to form sulphuric acid which greatly accelerated the leaching of carbonates. These soils are leached to a greater depth and have lower base status than other soils in the area which have developed from materials with similar texture but lower shale content. The relatively rapid permeability of the soil, high rainfall (34 inches/year) and great depth to the water table, also hasten the leaching.

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APPENDIX 1

Profile description—Door (Coupee) silt loam.

Location—St. Joseph County, Indiana—300 feet W and 120 feet S of NE corner of SW $\frac{1}{4}$ of NE $\frac{1}{4}$ Sec. 30, T38N, R1E.

Vegetation—wheat stubble seeded in red clover

Physiography—Terrace

Slope—1%

Elevation—745 feet

Natural Drainage and Permeability—Well drained, moderate permeability.

Parent Material—loamy material over shaley sand and gravel.

Ap-0 to 25 cm, black (10YR 2/1) silt loam; very dark brown (10YR 2/2) crushed; moderate fine granular structure; friable; neutral; abrupt smooth boundary.

A1-25 to 36 cm, black (10YR 2/1) silt loam, very dark brown (10YR 2/2) crushed; moderate medium granular structure; friable; medium acid; clear wavy boundary.

B1-36 to 53 cm, brown (10YR 5/) heavy silt loam, very dark grayish brown (10YR 3/2) on faces of most peds; moderate medium and fine subangular blocky structure; friable; many very fine random, inped, continuous pores with discontinuous very dark brown (10YR 2/2) linings in pores and old root channels; strongly acid; clear wavy boundary.

B21t-53 to 66 cm, brown (10YR 4/3) light clay loam; moderate medium subangular blocky structure; firm; thin discontinuous dark brown (10YR 3/3) clay films on faces of peds; common very fine, random, inped continuous pores with thin discontinuous very dark grayish brown (10YR 3/2) clay linings in pores and old root zones; few fine pebbles 2.5 cm and less in diameter; medium acid; clear wavy boundary.

B22t-66 to 84 cm, dark yellowish brown (10YR 4/4) light clay loam; brown (10YR 4/3) coatings on faces of peds; moderate coarse and medium subangular blocky structure; firm; few fine random, inped, continuous pores with discontinuous dark brown (10YR 3/3) linings; thin discontinuous clay films on faces of peds; few fine pebbles about 2 cm in diameter; distinct increase in sand content over above horizon; medium acid; clear wavy boundary.

IIB31-84 to 92 cm, dark brown (10YR 3/3) loamy sand; weak coarse subangular blocky structure; very friable; discontinuous very dark grayish brown (10YR 3/2) clay films; 10-15% gravel; common shale fragments; medium acid (pH 5.6); clear wavy boundary.

IIB32-92 to 112 cm, dark brown (7.5YR 4/4) medium and coarse sand; weak coarse subangular blocky structure; loose; few loamy sand bands dark brown (7.5YR 3/2) 2 mm thick; 10-15% gravel 1 to 2 cm in diameter, common shale fragments; medium acid; clear wavy boundary.

IIB33-112 to 132 cm, dark brown (7.5YR 4/4) medium and coarse sand; single grained; loose; 10-15% gravel 1 to 2 cm in diameter; numerous shale fragments; medium acid; clear wavy boundary.

IIC1-132 to 152 cm, pale brown (10YR 6/3) fine and medium sand; single grained; loose; few shale fragments; few pebbles; slightly acid; clear wavy boundary.

IIC2-152 to 183 cm, brown (10YR 5/3) fine gravel and medium and coarse sand; single grained; loose; 50% fine shale fragments; medium acid; clear wavy boundary.

IIC3-183 to 249 cm, light brownish gray (10YR 6/2) medium sand and dark brown (7.5YR 4/4) loamy sand bands 50 mm thick (bands make up about 50% of horizon by volume) and are irregularly spaced.

APPENDIX 2

Profile description—Door loam.

Location—Porter County, Indiana—380 feet west and 740 feet north of SE corner of SE $\frac{1}{4}$ Sec. 32, T35N, R5W.

Vegetation—Alfalfa

Physiography—Terrace

Slope—1%

Elevation—748 feet

Natural Drainage and Permeability—Well drained, moderate permeability

Parent Material—Loamy outwash high in shale over sandy and gravelly outwash high in shale.

Ap-0 to 20 cm, black (10YR 2/1) loam; moderate medium and fine granular; friable; medium acid; abrupt smooth boundary.

A1-20 to 33 cm, very dark brown (10YR 2/2) loam; moderate medium granular structure; friable; slight acid; clear wavy boundary.

A3-33 to 43 cm, very dark grayish brown (10YR 3/2) loam; weak medium subangular blocky and moderate medium granular structure; friable; very dark brown (10YR 2/2) lining in voids and fillings in worm casts; strongly acid; clear wavy boundary.

B21t-43 to 61 cm, brown (10YR 4/3) heavy loam; thin dark brown (10YR 3/3) coatings on faces of peds; weak medium subangular blocky structure; friable; thin discontinuous clay films on faces of peds and linings in some pores; few fine shale fragments and pebbles; very dark grayish brown (10YR 3/2) lining in some voids and in old root and worm channels; strongly acid; clear wavy boundary.

B22t-61 to 79 cm, brown (10YR 4/3) sandy clay loam; moderate medium subangular blocky structure; friable; thin discontinuous dark brown (10YR 3/3) clay films on faces of peds; common pebbles and shale fragments; few yellowish brown (10YR 5/6) dark reddish brown (5YR 2/2) and black (10YR 2/1) oxides; strongly acid; clear wavy boundary.

B23t-79 to 99 cm, yellowish brown (10YR 5/4) sandy clay loam; brown (10YR 4/4) coatings on faces of peds; moderate medium and coarse subangular blocky structure; friable; 15% fine gravel and shale; thin discontinuous dark yellowish brown (10YR 4/4 and 3/3) clay films on faces of peds and linings in some voids; few, fine yellowish brown (10YR 5/6) oxides; strongly acid; clear wavy boundary.

B24t-99 to 129 cm, brown (10YR 5/3) shaley loam (shale is dominantly less than 1 cm long and 5 mm thick); weak medium and coarse subangular block structure; friable; thin discontinuous dark brown (7.5YR 4/4) clay films on faces of peds and coatings on shale fragments; few fine yellowish brown (10YR 5/6) and yellowish red (5YR 4/6) oxides; very strongly acid; clear wavy boundary.

B31-129 to 167 cm, brown (10YR 5/3) and grayish brown (10YR 5/2) shaley loam; weak coarse subangular blocky structure; friable; common fine dark reddish brown (5YR 2/2) oxides; very strongly acid; abrupt wavy boundary.

B32-167 to 200 cm, strong brown (7.5YR 5/6) and dark brown (7.5YR 4/4) shaley loam; weak coarse subangular blocky structure; firm slightly cemented; yellowish red (5YR 4/6) thin clays films on faces of pebbles; this horizon is layered and high in oxides; medium acid; abrupt wavy boundary.

IIC-200 to 225 cm, light brownish gray (10YR 6/2) medium sand; single grained; loose; few shale fragments; medium acid.

Micromorphological Analysis of Selected Indiana Soils¹

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Abstract

Soil micromorphology is a technique using the principles of optical mineralogy for the detailed study of soils. This method is particularly useful in studies of soil genesis to demonstrate the occurrence or absence of certain processes during soil formation. Preparation of thin sections of unconsolidated soil materials presents special problems. A review of the methods used by the authors to prepare thin sections is presented. Principles of micromorphological analysis are demonstrated using selected Indiana soils.

This paper presents the methods used by the authors to prepare soil thin sections for micromorphological analysis, illustrates some of the features of the soil material, and discusses their genetic significance. The terminology used for describing micromorphological features is that suggested by Brewer (2).

Materials

The available equipment determines to a large extent the specific techniques used for sample preparation. In some cases it might be more convenient to use commercially prepared thin sections, but to examine a particular feature one can control better the area to be examined if he makes his own. The impregnation equipment used here consisted of a vacuum desiccator and vacuum pump with accessories (Fig. 1). After the samples were thoroughly embedded in plastic, a diamond saw (Highland Park Model EZ) and a polisher-grinder (Beuhler Ltd. Cat. No. 53-1502) were used to complete the thin sections.

The valve assembly at the top of the desiccator was removed and a rubber stopper inserted. The rubber stopper contained two glass tubes; one was connected to a vacuum pump and the other led from the impregnation mixture reservoir to the samples. The line leading to the vacuum pump contained a valve to release the vacuum, flask traps to prevent pump damage, and a manometer to measure the vacuum in the desiccator. The soil samples were put in lead cups or other suitable containers and placed in a circle beneath the delivery tube on a brass rotating platform. By placing the cups on the outside edge of the rotating platform many samples could be treated without having to break the vacuum. The platform was rotated by means of two magnets, one attached to the platform and the other on the outside.

The following chemicals were used in making the thin sections, Vestopal-H (obtained from Henley and Co., Inc., 202 E. 44th St., New York, N.Y. 10017), monostyrene, 60% methyl ethyl ketone peroxide, 1% cobalt-naphthenate, diamond saw lubricant and white gasoline.

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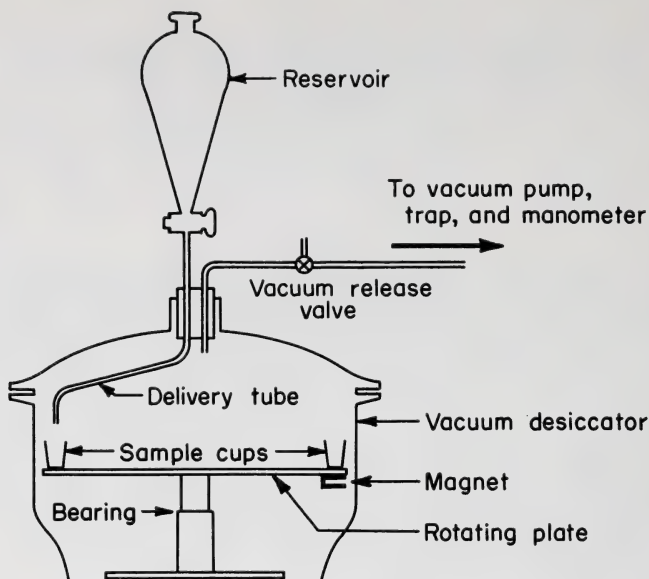


FIGURE 1. Vacuum apparatus for plastic impregnation of samples, after Brewer (2).

Methods

In this study two procedures for impregnation are discussed; one using a rapid cure technique and the other a slow cure. These methods are modifications of procedures suggested earlier by Altemüller (1), Jongerius and Heintzberger (3), Brewer (2), and Kubiena (pers. comm.).

A discussion of the theoretical aspects of the polymerization of the impregnation mixture is given by Jongerius and Heintzberger (3). It suffices to say here that Vestopal-H is a polyester resin that is viscous in the usual form. To lower the viscosity it is dissolved in monostyrene. This better enables the mixture to penetrate the sample, resulting in a more thorough impregnation. The catalyst, which might be considered an initiator, is a peroxide, in this case methyl ethyl ketone peroxide. The splitting of its oxygen bridges provides free radicals to activate the double carbon bonds in the resin and the styrene causing them to co-polymerize and form a three dimensional network structure. An accelerator, Co-naphthenate, is added to insure that the peroxide molecules will split, by reduction, at room temperature. Excess monostyrene is evaporated off during the course of the polymerization.

These are the steps followed in making thin sections:

- 1) Select samples which are small enough to be 1.5 cm below the top of the lead sample cups. Samples were usually 2 to 3 cm by 3 to 4 cm.
- 2) Dry samples overnight in a 105°C oven and cool in a desiccator. It is important that the samples be free of water for the plastic completely to impregnate the sample.
- 3) Prepare impregnation mixtures. The slow cure mixture suggested by Jongerius and Heintzberger (3) has this composition ratio:

Vestopal-H	1000 ml
Monostyrene	667 ml
1% Cobalt-octoate, accelerator	1.3 ml
50% Cyclohexanone peroxide, catalyst	2.7 ml

In this mixture we substituted 1% cobalt naphthenate for cobalt octoate, and 60% methyl ethyl ketone peroxide for 50% cyclohexanone peroxide.

The rapid cure mixture of Kubiena had this composition ratio:

Vestopal-H	1000 ml
Monostyrene	250 ml
Co-naphthenate	3.1 ml
Methyl ethyl ketone peroxide	6.2 ml

Special care must be taken when preparing this mixture to avoid bringing the Co-naphthenate and methyl ketone peroxide in contact with each other as this will result in an explosion. To avoid this problem the Co-naphthenate and methyl ethyl ketone peroxide were added separately to the Vestopal-H and monostyrene mixture. The Co-naphthenate is a deep purple color which can be seen readily until it is thoroughly mixed with the other components. When the entire mixture is clear it is safe to add the methyl ethyl ketone peroxide. At temperatures higher than 22°C only one-half of the Co-naphthenate and methyl ethyl ketone peroxide are used.

4) Place the impregnation mixture under moderate vacuum to remove air bubbles that have been caused by stirring.

5) Place the samples in the lead cups on the outside edge of the rotating circular platform in the vacuum desiccator and apply a vacuum of 63 cm of mercury as recorded on the manometer. Leave the soil samples under vacuum for 20 min to remove entrapped air sufficiently.

6) Pour plastic into the funnel and open the valve to allow the plastic to flow out the spout and down the side of the cup. Be careful not to put the plastic on the sample itself. This avoids the problem of plastic entering the soil sample from more than one direction, causing incomplete impregnation. Initially, the sample cup is filled to about one-third full and allowed to stand until plastic has moved to the top of the sample by capillary action. At this point, the sample is allowed to set for $\frac{1}{2}$ hour and then the cup is filled to the top. An attempt is made to keep the plastic 1.5 cm above the surface of the sample. This is to allow for the evaporation of the excess monostyrene without exposing the surface of the sample.

7) Leave the samples in the desiccator under vacuum for 12 hours. At the end of this time, place the samples under a ventilated hood to harden. The expected time for completion of the rapid cure samples is 4 to 7 days. The slow cure samples are expected to take 4 to 10 weeks. Our experience has shown that the rapid cure method should be used only on coarse-textured samples, because incomplete impregnation is common in other soils. The slow cure method can be used for either fine or coarse textured samples.

Monostyrene lost by evaporation is replaced by the following mixture:

Vestopal-H	1000 ml
Co-naphthenate	2.5 ml
Methyl ethyl ketone peroxide	2.5 ml

No monostyrene is added at this stage because little penetration is needed since the sample is already saturated with partially polymerized mixture.

8) After curing, the samples prepared according to the two different methods are handled in the same manner. Remove the sample containers. Saw off an approximately $\frac{1}{4}$ -inch thick section and trim with the diamond saw.

9) At this point, check the section for thoroughness of impregnation with a binocular microscope. The section should be surface reimpregnated with the refilling mixture if needed.

10) Obtaining a smooth surface on the section to affix to the glass slide is a critical part of the procedure because this is the surface that will be seen in the finished thin section. This polishing is done manually on a piece of 1-inch thick plexiglass using Carborundum papers of 240, 320, 400 and 600 grit moistened with diamond saw lubricant. Water cannot be used because even successfully impregnated samples will have clay and organic matter that react with the water and cause pits at the surface. Successively finer

abrasive papers are used to remove imperfections left by the coarser papers. White gasoline is used to clean the diamond saw lubricant and loose particles from the surface of the section.

11) Cement the smooth side of the section to the glass slide by the same mixture used to refill the slow cure samples. Place the plastic mixture on the polished surface of the section and then place the glass slide on the polished surface and remove air bubbles. Clamp the slide and affixed sections together and allow to harden.

12) After the plastic has cured, reduce the size of the section to about 1/16 inch by cutting with the diamond saw. A special holder was made for the diamond saw to hold the glass slides.

13) The final grinding is similar to that described for preparation of the section for mounting on the glass slide. Use the grinding wheel with 120 and 240, 320 or 400 grit abrasive papers to reduce the section to approximately 60u as determined with a petrographic microscope and interference color chart. Complete the final grinding with 600 grit paper. The final section should have a thickness of 30u which is first order gray to yellow for quartz.

14) Complete the thin section by affixing a cover glass with the same plastic as used for mounting. The procedure used is to place the thin section on a table and apply a thin layer of plastic on it. Attach the cover glass from one edge in a hinge-like motion. Any air bubbles induced should be removed.

Results and Discussion

Figures 2 and 3 are photographs of various micromorphological features found in some Indiana soils.

Figure 2, Photograph 1 is a photomicrograph of a thin section made from a Miami B2t horizon. The Miami soil is classified as a Hapludalf in Soil Taxonomy (4). The feature labeled CH is a longitudinal section of a root channel which continues across the slide but is masked by an argillan, a concentration of oriented clay particles, labeled A. It is likely that this argillan covered the entire void but parts of it were removed when the section was polished. The remainder of the material is considered to be the s-matrix, the soil matrix material within peds, labeled SM with the larger grains being quartz. This example shows the importance of channels and planes in the movement of water through soils. Clay is carried in aqueous suspension and as the water moves into the s-matrix, clay particles are deposited on the surface as argillans. These small regions that are extremely high in clay result in the overall fine texture of the entire horizon.

Photograph 2 in Figure 2 is from a fragipan in the Bx horizon of a Clermont soil (Ochraqualf). The features labeled P and CH are cross sections of root channels or former root channels, and the s-matrix is labeled SM. Again these channels are lined by argillans and the clay is highly oriented perpendicular to the plane of the photograph. Unlike the channel shown previously, the channel, P, has at least four stages of development. Starting with an initial channel, an argillan, A, was deposited, followed by deposition of an argillan high in manganese and iron, B. The void then was filled by a cutan, a concentration of mobile soil materials, low in manganese and iron, C. Its birefringence and its appearance in the photograph indicate that the cutan is primarily silt with some clay. The last filling is primarily manganese and iron oxides and constitutes a pedotubule (P). These different stages have resulted from different soil conditions; one possibility is a change in oxidation state of the surrounding soil material.

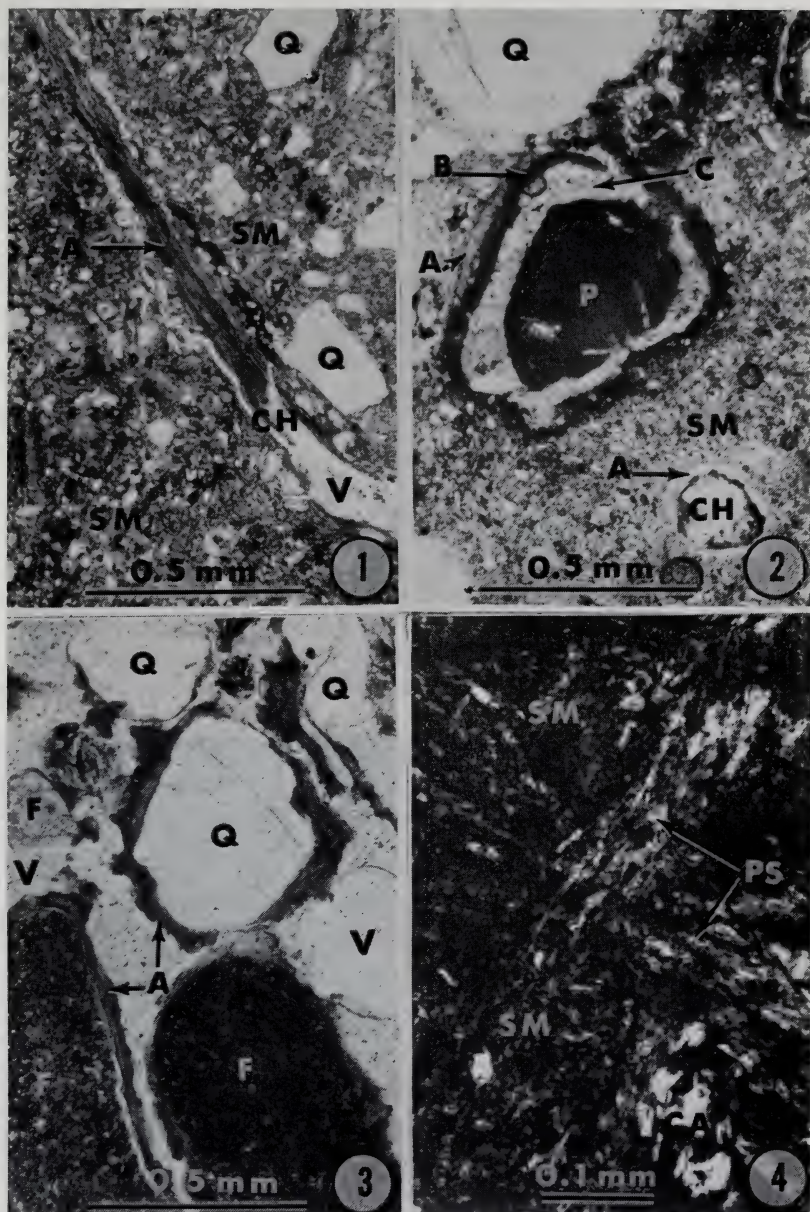


FIGURE 2. Photomicrographs in plane polarized light of: 1) Miami B2t, 2) Clermont Bx, 3) Ockley IIB2t; and under crossed polarizers, 4) paleosol in Illinoian till. Features illustrated: A (argillan), B (argillan high in iron and manganese), C (cutan), CA (clay aggregate), CH (channel), F (feldspar), P (pedotubule), PS (plasma separation), Q (quartz), SM (s-matrix), and V (void). All thin sections were prepared using slow cure methods.

Photograph 3 in Figure 2 is of a thin section from an Ockley IIB2t horizon (Hapludalf). This soil has coarser soil particles than the soils in the pictures above. The slide shows primarily skeleton grains and argillans. The skeleton grains are quartz, labeled Q, and weathered feldspar, F. The dark features surrounding each of the skeleton grains, A, are argillans. These grain argillans coat some sand grains and bind neighboring grains together. Practically all of the clay in the horizon is oriented, suggesting that it has been transported and re-deposited.

Photograph 4 of Figure 2 is a thin section of the B horizon of a paleosol developed in Illinoian till. The picture shows the s-matrix, labeled SM; plasma separations (PS), rearrangements of soil constituents; and an aggregate of clay particles in similar orientation (CA). The plasma separations are arranged in two linear patterns at right angles to each other. They probably are the result of external stresses on the soil.

Photographs 5 and 6 of Figure 3 are from a Miami B2t horizon. Picture 5 was taken in plane polarized light and Picture 6 was taken under crossed polarizers. These pictures again demonstrate the significance of voids in the movement of clay and water in the soil profile. The features labeled CH are root channels lined by argillans, A. These are surrounded by the s-matrix, labeled SM. The argillan is not highly developed. This would indicate that this particular void may have had less water moving through it than moved through the other voids

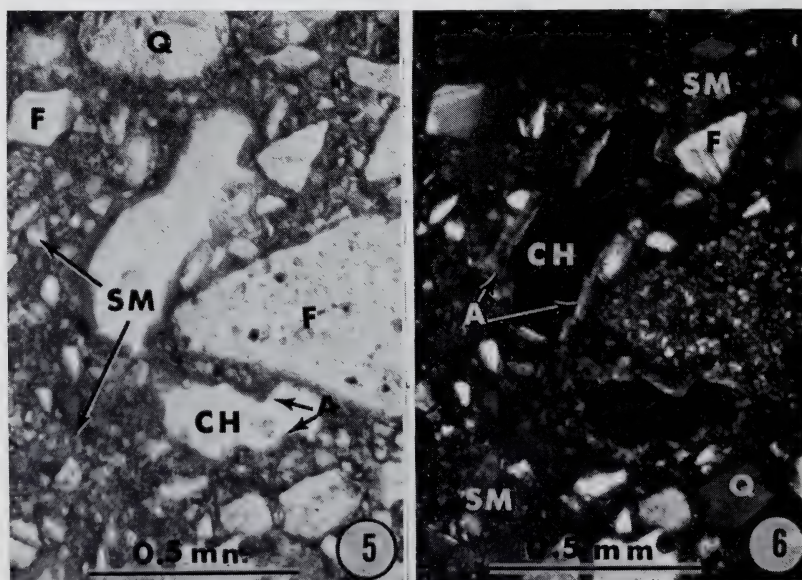


FIGURE 3. Photomicrographs of Miami B2t, 5) plane polarized light and 6) crossed polarizers. Features illustrated: A (argillan), CH (channel void), F (feldspar), Q (quartz), and SM (s-matrix).

pictured. There is a considerable difference between the features seen under plane polarized light and under crossed polarizers. The weathered feldspar, F, which shows clearly under crossed polarizers is very similar to quartz in plane polarized light. Similarly the argillan which shows its oriented nature by birefringence under crossed polarizers is not clear at all in plane polarized light. The unusual shape of the root channel is probably due to an oblique cut.

These results indicate that much information can be obtained about soil forming processes by micromorphological analysis. The new soil classification system, Soil Taxonomy (4), with its emphasis on natural properties shows the need for micromorphological analysis. However, it is also clear that more basic research needs to be done to correlate the soil forming processes with specific micromorphological features.

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Productivity of Selected Indiana Soils¹

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Abstract

Corn (*Zea mays* L.) grain yields of 10 soils from five high yielding farms were compared for 6 years. One swell soil (Crosby, Reesville, or Iva series) was compared with an adjacent swale soil (Brookston, Ragsdale, or Zipp series) in the same field on each high yielding farm. Both the range in yields and the coefficients of variation of yields tended to be higher and the mean yields tended to be lower for the swell soils. In clay pot trials conducted outside in June, the number of corn plants that emerged from one Crosby silt loam was significantly less than from each of six other soils and another Crosby silt loam from the high yielding farms. Both dry weight and height of plant tops from high ground soils tended to be lower than those from swale soils in these pot trials. In a comparison of two sources of corn grain yield data, three soil series and 13 yields from each source of data were used. On the same soil series, grain yields from objective yield surveys of the Statistical Reporting Service tended to be lower and more variable than those from the high yielding farms.

Introduction

In 1957 Rust and Odell (6) reported their methods used in evaluating productivity of Illinois soils. Multiple curvilinear regression analyses were used to relate input data to yield in relation to soil types on approximately 20,000 fields. They found that approximately 100 to 200 fields were needed to make reasonably accurate estimates of crop yields for a soil type or an association of two closely related soils under the conditions observed. In 1958, Odell (3) reported how he used soil survey information, experimental plot data, and farm production records to estimate yields by soil types. Recently, a small amount of information on yields by soil type in Indiana was published by Barber (1) and by Stivers (8). In 1972, Purdue (2) made estimates of crop yields of Indiana soil series and management types by management productivity groups. Some similar information published by Odell and Oschwald (4) is applicable in Indiana. Even with all of these publications, more information from field trials about soil type productivity in Indiana is needed.

The purposes of this paper are: 1) to report corn (*Zea mays* L.) yield data from field and pot experiments on selected soil types, and 2) to compare corn yield data from the objective yield surveys of the Statistical Reporting Service with data from high yielding farms on selected soil series or types.

Methods and Procedure

Field Trials on High Yielding Fields

Corn grain yields on 10 soils from five high yielding farms in central and north central Indiana were compared over a 6-year period.

¹ Journal Paper No. 5280. Purdue University Agricultural Experiment Station.

Four years of data on fertilization, cultural practices, selected chemical properties and methods of yield sampling of the soils on these high yielding farms were previously presented by Stivers (8). Fertilization, cultural practices, and methods of yield sampling were approximately the same during the last 2 years of the experiment, 1971 and 1972, as in the first four, 1967-1970. Yields are reported on the basis of 15.5% moisture in the grain.

The 10 soils included three soil series located on ridges or swells and three soil series located in swales or slightly depressed areas. The series and 7th Approximation classification of the swell soils are: 1) Crosby, fine, Aerlic Ochraqualf; 2) Reesville, fine silty, Aerlic Ochraqualf; and 3) Iva, fine silty, Aerlic Ochraqualf. The same classification of the swale soils is: 1) Brookston, fine loamy, Typic Argiaquoll; 2) Ragsdale, fine silty, Typic Argiaquoll; and 3) Zipp, fine, Typic Haplaquept. All of the 10 soils except the two on the McKowen Farm were classified and described in the field by D. P. Franzmeier and A. L. Zachary. They also classified all of the above soils as mixed mesic.

Slope and erosion were not important variables among swell soils. Harvest areas were taken from the top of nearly flat parts of the ridges or swells where slope was less than 2%. Variations within soils are within the variations accepted for the named series.

One swell soil was compared with an adjacent swale soil in the same field on high-yielding farms. Adjacent swell and swale soils always received the same chemical and cultural treatments because the same rows were used in both soil areas. As previously explained (8), five sublocations were harvested and averaged to obtain the yield of one soil type in one year. Since the Neyhouse Farm did not cooperate in 1972, these two yields were not obtained. The method of missing values of Snedecor and Cochran (7) was used to supply two substitute values so that one analysis of variance could be used for all years and all soils. The analysis of variance used was that suggested by W. E. Nyquist. Sources of variation and their accompanying degrees of freedom were: 1) years, 5; 2) farms, 4; 3) years $\times$ farms, 20; 4) soils within farms, 5; and 5) years $\times$ soils within farms, 23.

Pot Trials of High Yielding Soils

Corn was grown outside in pots in June 1973 on the eight soils from the four high yielding farms that completed the field trials in 1972. Four fertilizer treatments were used on each of the eight soils. Fertilizers were applied on the basis of a weight of 2,000,000 lbs/acre (2,240,000 kg/ha) for a plow furrow depth (6 inches or 15 cm) of soil. The fertilizer treatments were 0-0-0, 0-87-167, 200-87-167, and 400-87-167 in lbs/A (0-0-0, 0-97-187, 224-97-187, and 448-97-187 in kg/ha) of nitrogen (N), phosphorus (P), and potassium (K). Fertilizers were mixed uniformly with the soil in each treatment prior to filling the pots and planting. Three replications of all treatments (eight soils and four fertilizers) were used in a completely randomized design. Eight

seeds of Beck's 80X hybrid seed corn were planted per pot on June 8, 1973. The 2.20 lb (1.00 kg) of soil in each pot was completely saturated with tap water, and any excess was allowed to drain. The pots and contents were weighed and then placed on boards between two ranges of greenhouses in full sunlight near the Life Science Building, West Lafayette, Indiana.

On June 14, counts of emerged seedlings were made. Six additional seeds per pot were then planted in each of 24 pots having less than eight plants. On June 18, all pots were thinned to six plants per pot. Later as seedlings emerged all plants over six per pot were removed.

Water was applied by rainfall and by hand sprinkler hose daily or more often as needed. Twice during the experiment all pots were weighed. Water was added to bring total pot weights up to 80% of soil saturation as determined from previous weights.

Tops of corn plants were harvested July 1, dried at 140°F (60° C), and weighed.

Data of High Yielding Fields and Statistical Reporting Service Compared

Half of these corn yield data are from the Department of Agricultural Statistics and the U. S. Department of Agriculture's Statistical Reporting Service cooperating at Purdue University, Earl L. Park, Agricultural Statistician in charge. Corn yields were obtained by objective yield surveys on cooperating farms in randomly picked segments of land. Each segment usually contained two or three farms. Names of farmers were not known.

In the objective yield surveys two areas to be subsampled were picked by random methods in each corn field in which yields were determined. Each subsample was 15 feet long and 2 rows wide. Stalks and ears were counted, and sample ears were sent to the State Statistical Reporting Service laboratory for weight of grain, grain moisture determinations, and yield calculations.

Aerial photographs containing the cornfields harvested in the objective yield surveys were matched with soil survey maps made available by Donald P. Franzmeier, Agronomy Department, Purdue University. Where there were two different soil types in the two subsamples in the same field the subsample data were not used in this report.

The other half of the corn yield data by soil types came from selected high yielding farms previously mentioned. For the comparison with the Statistical Reporting Service data single subsample values, rather than the average of five subsample values reported in Table 1, were used. Prior to running analyses of variance, F tests of significance, standard error of the mean difference, and t tests, Bartlett's test of homogeneity of variance was used to compare both sets of data. Pearson and Hartley's (5) tables were used to interpret the Chi-square value obtained.

Results and Discussion

Field Trials on High Yielding Fields

The highly significant (1% level) interactions between years and farms as measured by mean corn grain yields can be seen in Table 1. For example, corn grain yields on the Franklin Farm were relatively higher, in comparison with those of the other farms, in 1971, with 186 bu/acre (11,666 kg/ha) while in other years they were relatively lower. Since the total July and August rainfall of 4.58 inches (116.3 mm) in 1971 was less than normal, sufficient rainfall was not the explanation for the high yields on the Franklin Farm.

The range in corn grain yields was greater on the swell soils (Crosby, Reesville, and Iva) than on the swale soils (Brookston, Ragsdale, and Zipp) when calculated according to the following equation:

$$\frac{\text{Highest yield Soil A} - \text{Lowest yield Soil A}}{\text{Highest yield, Soil A}} \times 100 = \frac{\% \text{ variation in range of grain yield}}{\text{yield}}$$

On the five swell soils variation in range of grain yields was from 27.7% to 41.9% with a mean of 34.1%; on the swale soils the variation in range was from 13.5% to 31.6% with a mean of 24.5%. Coefficients of variation were also greater on swell soils than on swale soils in four out of five comparisons in Table 1.

Average corn grain yields of the swell soils, 148 bu/acre (9,280 kg/ha), were 10 bu/acre (627 kg/ha) lower than those of the swale soils, 158 bu/acre (9,910 kg/ha). As shown by the larger "t" value in Table 1, the largest difference between average yields of swell and swale soils was between Crosby silt loam and Brookston silt loam on the McKowen Farm. This difference was 31 bu/acre (1,944 kg/ha). Even though the differences were much smaller in the other comparisons, the same trend was evident on the other high yielding farms. There were no meaningful differences among farms in corn grain yields.

Insufficient rainfall in 1967 in July and August on the Franklin Farm, 1.24 inches (31.5 mm), and on the McKowen Farm 2.32 inches (58.9 mm) appeared to be the cause for the low yields on the Crosby silt loam on these two farms (Table 1). Field observations indicated that there was much more leaf rolling on the Crosby than on the Brookston and/or Ragsdale soils in dry weather. Too much rainfall, 18.9 inches (480.0 mm) as well as detasseling operations and damage to the plants probably contributed to relatively lower yields on the Neyhouse Farm in 1971.

Pot Trials of High Yielding Soils

The number of corn plants that emerged from planted seed in Crosby silt loam from the McKowen Farm (5.08 plants per pot) was significantly (1% level of probability) less than the number in all other soils (7.25-7.83) even though the number of seeds planted (8 per pot)

TABLE 1. *Relation of farm, soil type, rainfall, and year to yield of corn grain on high yielding farms, 1967-1972.*

Farm	Soil type	Yield in Bushels per Acre						Coefficient of variation %	t for standard error of mean difference
		1967	1968	1969	1970	1971	1972		
H. McKowen	Crosby silt loam, bu/A	95	146	145	115	152	133	16.8	2.53*
	Brookston silt loam, bu/A	153	153	170	163	198	138	12.7	
	Mean yield bu/A	124	150	157	139	175	136		
	Rainfall, July + Aug., inches	2.32	7.22	8.59	7.41	6.86	---		
		---	---	---	---	---	---		
W. Franklin	Crosby silt loam	118	141	169	142	203	146	153	0.39
	Ragsdale silty clay loam	151	160	175	142	168	152	158	
	Mean	135	150	172	142	186	149	156	
	Rainfall, July + Aug., inches	1.24	3.96	8.63	4.18	4.58	---		
		---	---	---	---	---	---		
L. Priebe	Reesville silt loam	116	124	143	153	176	149	144	0.55
	Ragsdale silty clay loam	153	119	158	166	155	148	150	
	Mean	135	122	150	160	166	148	147	
	Rainfall, July + Aug., inches	9.19	7.01	8.80	6.52	9.47	5.94		
		---	---	---	---	---	---		
J. Bosstick	Iva silt loam	188	136	167	161	153	143	158	0.48
	Ragsdale silt loam	164	147	169	170	165	155	162	
	Mean	176	142	168	165	159	149	160	
	Rainfall, July + Aug., inches	5.75	5.46	7.67	3.90	7.47	---		
		---	---	---	---	---	---		
E. Neyhouse	Reesville silt loam	166	161	170	153	120	---	154	0.42
	Zipp silt loam	190	146	180	156	130	---	160	
	Mean	178	154	175	155	125	---	157	
	Rainfall, July + Aug., inches	13.41	9.00	17.99	5.18	18.90	---		
		---	---	---	---	---	---		
	Mean, all soils, bu/A	149	143	165	152	162	146	153	
		---	---	---	---	---	---		

* Significant at the 5% level

1 Missing value figures for analysis of variance: Reesville = 146, Zipp = 152

was the same (Table 2). The reason appeared to be that water applied had not reached the kernels in sufficient amount in this Crosby soil because of surface sealing. There was no meaningful difference among the remaining seven soils, one of which was also a Crosby silt loam. Previously reported field studies of Stivers (8) pointed out that corn stands on high ground or swell soils were usually lower than those on adjacent low ground or swale soils. In these pot studies the same relationships between corn stands appeared to be true on Crosby and Brookston soils from the McKowen Farm.

TABLE 2. *Relation of corn plant growth in pots to farm, soil type, and fertilizer treatment.*

Farm and Soils or lbs/A of N-P-K	No. plant ¹ per pot 6-18-73 Avg.	Dry wt. ¹ tops per pot g	Max. height ¹ per pot cm	Avg. color ¹ per pot
H. McKowen, Crosby silt loam -----	5.08	Not Rep. ²	Not Rep. ²	Not Rep. ²
H. McKowen, Brookston silt loam -----	7.83	4.54	52	2.67
W. Franklin, Crosby silt loam -----	7.67	3.58	46	2.17
W. Franklin, Ragsdale silty clay loam ----	7.75	4.54	51	2.50
L. Priebe, Reesville silt loam -----	7.25	4.54	53	2.75
L. Priebe, Ragsdale silty clay loam -----	7.83	5.45	53	2.75
J. Bosstick, Iva silt loam -----	7.50	3.92	49	2.42
J. Bosstick, Ragsdale silt loam -----	7.25	4.49	51	2.33
Least Significant Difference 5% level -----	0.84	.70	4	Not Sig.
Least Significant Difference 1% level -----	1.20	1.00	6	Not Sig.
0—0—0 -----	6.92	3.01	44	2.19
0—87—167 -----	7.46	3.34	46	2.24
200—87—167 -----	7.33	5.03	54	2.71
400—87—167 -----	7.38	6.37	58	2.90
Least Significant Difference 5% level -----	Not Sig.	0.52	3	0.41
Least Significant Difference 1% level -----	Not Sig.	0.69	4	0.54

¹ Figures are from three replications. Color: 1 = yellow, 5 = dark green.

² Not Rep. = Not reported because data available are partially the result of re-planting.

Among the seven soils having approximately equal plant populations dry weights of corn plants were significantly (1% level of probability) different from each other (Table 2). As with grain yields, dry weights from the swale soils tended to be greater than those from swell soils taken from the same farm. Dry weights of those pots treated with N were significantly (1% level) higher as rates of N increased. Maximum heights of corn plants tended to show the same relationships to soils and fertilizer treatments that dry weights had (Table 2). The amount of green color in the corn in each treatment was greater as rates of N increased.

Data of High Yielding Fields and Statistical Reporting Service Compared

It took 2 years of gathering objective yield data of the Statistical Reporting Service (SRS) to get the comparisons given in Table 3.

The average corn yield of the SRS data given in Table 3 was 127 bu/acre (7,965 kg/ha), while that for high yielding (HY) farms was 145 bu/acre (9,094 kg/ha). In two of the three soils series compared in Table 3 the means of the SRS data were lower and their standard errors of the mean were higher than those of the HY data. In the third comparison the reverse was true.

Since as many as 339 or 559 corn grain yields (Table 3) from SRS data may be required to obtain an estimate of the mean yield of a soil series to within a range of plus or minus 5 bu/acre (314 kg/ha), it is obvious that SRS data are sometimes extremely variable.

TABLE 3. *Comparison of corn yield data from two sources, 1971 and 1972.*

Soils	Data ¹ source	Yields in Bushels per Acre individual trials						Standard error of the mean	No. ² of yields required L=X±5
		1972							
Brookston sil or siel	SRS	153	154	135	152	150	149	± 3.51	19
Brookston sil	High yield	127	142	127	157	136	138	± 5.59	48
		1971-1972							
Crosby sil	SRS	99	53	102	144	---	100	±18.59	559
Crosby sil	High yield	140	159	136	134	---	142	± 5.72	53
		1971-1972							
Reesville sil	SRS	160	143	106	100	---	127	±14.47	339
Reesville sil	High yield	176	147	161	144	---	157	± 7.34	87

¹ SRS = Statistical Reporting Service data.

High yield = Individual subsample yields from McKowen (Brookston silt loam and Crosby silt loam) and Priebe (Reesville silt loam) farms.

² Probability of 95:5. L = limit; X = mean obtained in bu/A.

Application of Results

This report indicates that continuing the time consuming work of obtaining SRS crop yields and finding the soil types for these fields may be of questionable value for evaluating crop yields of important soil types in Indiana. Variation in yields on the same soil type may be very great, this requiring a very large number of yields to get a good estimate of the mean yield of a soil type.

From the pot experiment reported it can be inferred that eliminating the weather variable from comparing soil type productivity is quite desirable and perhaps within the realm of possibility. Moving soils by horizons to a common location and placing them on a common subsoil base could drastically improve the testing procedure for comparing soil type productivity, it is believed.

Summary and Conclusions

- 1) In the 6 years and seven different soil types sampled on high yielding farms, corn yields of the swell soils tended to be lower and more variable than those of the swale soils. Results of a

pot experiment with corn on six of the seven different soil types supported the field research findings.

- 2) Objective yield data of the SRS were compared with individual subsample yields of corn from selected high yielding farms by soil type. In these 13 comparisons the corn yields of the SRS soil series tended to be lower and more variable than those from the same soil series on high yielding farms.

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Soil Water Tables Under Corn on Tile-Drained Chalmers Silt Loam¹

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Abstract

Soil moisture in the corn root zone and the depth of the water table on tile-drained Chalmers silt loam near Lafayette, Indiana, were measured under early- and late-planted corn in the 1971-1973 growing seasons. From relations developed between available soil moisture and the drop of the water table, the amount of upward flux of water into the corn root zone was estimated. The upward flux of water from the water table was estimated to range from as little as 1 per cent of the actual evapotranspiration from corn in the first planting in the wet season of 1972 to 11 per cent in the first planting of 1973, a year with several extended dry periods. High corn yields are dependent upon an adequate supply of soil moisture. Shallow water tables which underlie much of Indiana's cropland can furnish a significant part of the water requirement in summers with periods of insufficient rainfall.

Introduction

Artificial drainage is necessary for efficient crop production on nearly $\frac{2}{3}$ or almost 9 million acres of the agricultural cropland in Indiana. The soil water table has usually been considered a farming liability, especially in the spring when often, even with drainage tiles, frequent rains may cause the water table to rise to the surface and delay land preparation and planting operations. Occasionally, rains in the fall may again bring the water table to the surface before harvesting operations are completed, although the probability for this is less than in the spring.

During a field experiment to quantify the effect of weather on corn growth and yields at the Purdue Agronomy Farm, it became evident that a soil water table under the experimental plots had a role in the moisture supply for corn roots during the main part of the growing season. More detailed observations of the variation in height of this water table were made in 1971-73 seasons. The results and interpretations reported here indicate that the flux of water upward from the water table can be a significant part of the water supply for evapotranspiration, especially in a dry year. The possible value of this phenomenon can be appreciated when it is realized that a similar water supply probably underlies much of Indiana's 9 million acres of drained cropland.

Review of Literature

The effect of downward percolation on measuring evapotranspiration by soil moisture changes has been recognized in irrigation areas (12). Capillary rise has been studied most extensively in the European lowlands, and with regard to subirrigation (11).

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Several methods of estimating deep percolation have been used. Since it is a type of unsaturated flow in porous media, theoretical methods can be used if pressure gradients and hydraulic properties are known as functions of moisture content (5, 7). van Bavel *et al.* compared soil moisture changes in a lysimeter to those in a regular field and found that as much as 4 mm per day could flow up into a sorghum root zone from a supply which had percolated downward after irrigation (10). Jaworski found a strong diurnal fluctuation in a shallow water table under young poplar trees (6). The water table dropped during the day with maximum evapotranspiration and rose during the night with side inflow and capillary rise.

Many investigators have observed the presence of water tables, and others have studied the relation between water table depths and yields. Harris *et al.* found that the highest yields of maize on a muck soil occurred when the water table was at 80 cm (4). Van't Woudt and Hagan summarized the effect of water tables on yields in different kinds of soils (11). Influences of water tables on corn yields in Indiana were studied indirectly by Galloway and Sisson as yield variation with distance from tile lines in different years and soil (2). Harlan measured the depth of the water table for 1967 to 1971 under Brookston and Crosby soils in central Indiana (3).

Experimental Techniques

A full season corn hybrid² was planted on Field 32 of the Purdue University Agronomy Farm, West Lafayette, Indiana, on two planting dates in each of 3 years. To help interpret the soil water measurements with regard to the development of the corn crop the phenological dates are shown in Table 1. Both early and late crops were planted in 85-cm rows and hand-thinned to plant population densities of 62,000 plants per hectare, a typically high commercial stand in Indiana.

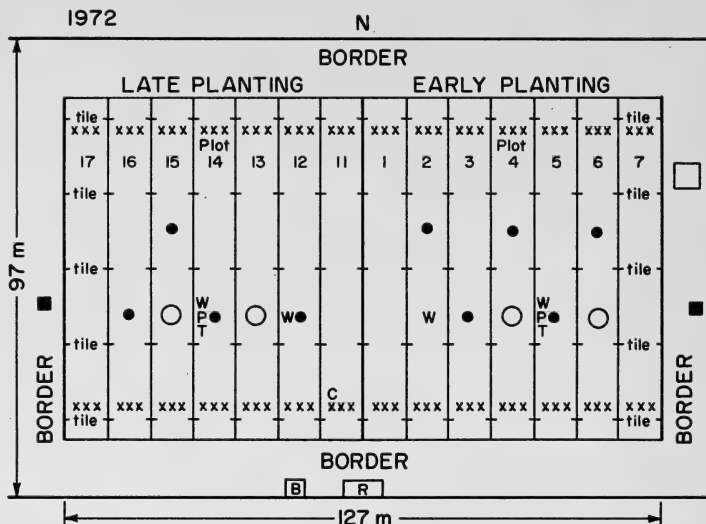
The soil was Chalmers silt loam, a Typic Argiaquoll, and probably as level and homogeneous as any soil found on glacial till. Soil bulk density and the water remaining in the soil at 15 atmospheres tension for each 30-cm layer are provided in Table 2. The plots were tiled with the tile lines approximately 19 m apart and 0.95 to 1.05 m deep. The tile lines are shown in Figure 1.

The soil moisture in the corn root zone was measured all three years with a neutron probe.³ The locations of the neutron probe access tubes are shown for 1972 in Figure 1. Location of instruments and field plot design were similar in 1971 and 1973. There were five (six in 1973) access tubes in each planting and they were located about halfway between drain tiles in 1972 and 1973, but were approximately over the drain tiles in 1971. Observations with the neutron probe were taken by 30-cm increments in the top 1.5 m, and were calibrated with

² SX-29 PAG in 1971 and 1972, courtesy of the late Dr. Wayne Whitehead; and Pioneer 3369A in 1973.

³ Troxler depth probe, courtesy of Mr. Walter Stirm, Advisory Agricultural Meteorologist, National Weather Service, Purdue University, West Lafayette, Indiana.

gravimetric measurements at the time of placing the access tubes. Measurements were taken twice a week in 1971 and once-weekly in 1972 and 1973.



- W - Water table tubes B - Pressure chamber
 X - Plants for leaf area determination and stem diameters
 O - Radiation tower □ - Stress plot
 ● - Soil moisture access tubes
 C - Time-lapse movie camera
 R - Recorder shed ■ - Insect light trap
 T - Battery of tensiometers P - Battery of psychrometers

FIGURE 1. Weather and corn experimental plot layout on Field 32, Purdue University Agronomy Farm, West Lafayette, Indiana, 1972.

Each year, four 2.5-cm diameter conduit pipes, sealed on the lower end and with small holes drilled in the lower 1 m, were installed to a depth of 2.5 m. Two water table pipes were used in each planting, and on one of the pipes in each planting water stage recorders were mounted for continuous recording of the water table height. The depth of the water table in all pipes was measured with a steel tape and stick at least once weekly.

Results and Discussion

The plant available water—amount above 15 atm retention—in the top 105 cm for both the first and second plantings for 1971, 1972, and 1973 growing seasons is shown as the top set of curves in Figure 2. The top 105 cm represent the depth of the root zone at maximum development. Daily soil moisture amounts between neutron measurements were estimated with a soil moisture simulation program.

TABLE 1. 1971-1973 Purdue Agronomy Farm weather and corn experiment phenological data.

Season	Phenological Dates				Yield Bu/acre
	Planted	Emerged	Silked	Matured	
1971 First planting -----	4/28	-----	7/16	9/2	167
Second Planting -----	5/28	6/3	7/27	9/16	156
1972 First Planting -----	5/3	5/14	7/21	9/11	142
Second Planting -----	6/1	6/8	8/11	10/4	140
1973 First Planting -----	5/1	5/13	7/20	9/13	183
Second Planting -----	5/24	6/3	7/26	9/20	160

With no upward flux of water from the water table, the available soil moisture in the top 105 cm is a direct reflection of the precipitation-evapotranspiration balance. Evapotranspiration causes a gradual decrease in the curves, as moisture is extracted by the corn roots from the entire profile, but preferentially from the top 30 cm with adequate available soil moisture. Precipitation occurrences can be observed on the figures as abrupt increases in the soil moisture content, with the amount of increase equal to the rainfall received less the evapotranspiration for the day of precipitation. The neutron measurements, by 30-cm layers, have been published in the Annual Summary, Indiana, Climatological Data (9) for the specific year.

TABLE 2. Soil bulk density and water remaining at 15-atmospheres tension for 30-cm layers of Chalmers silt loam, Field 32 Purdue University Agronomy Farm.

Depth (cm)	Avg. Bulk Density (g/cc)	15-atm Water Retention (mm/30 cm)
0- 30	1.54	47
30- 60	1.48	53
60- 90	1.55	53
90-105	1.68	25
0-105	----	178

The average depths of the drain tiles are indicated by the short horizontal bars along the left ordinate of the figures. Tile lines are all nearer the surface (~ 95 cm) under the first planting on the east side of the field than under the second planting (~ 105 cm).

The depth of the water table is shown as the lower set of curves in the same figures. Initially, following winter and spring rains, both the soil moisture and water table levels are high and then decrease with deep drainage and increasing evapotranspiration demands during the growing season. The recharging process came early in 1972, the wettest September on record over much of Indiana, when the water table (Fig. 2b) rose above the tile lines by mid-September. The fall of 1972 will be remembered in Indiana for its high moisture corn and delayed harvesting. It is this dependable winter recharging of soil moisture in the crop root zone, however, which provides the more stable high grain production potentials in the eastern corn belt than in the

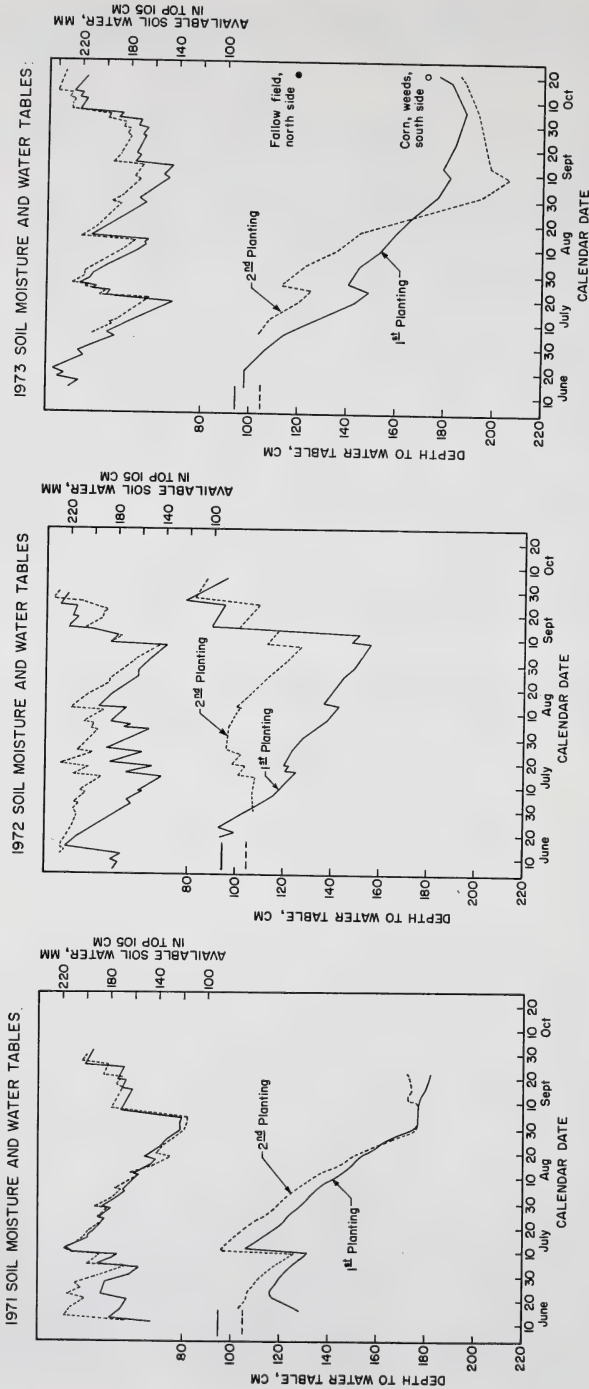
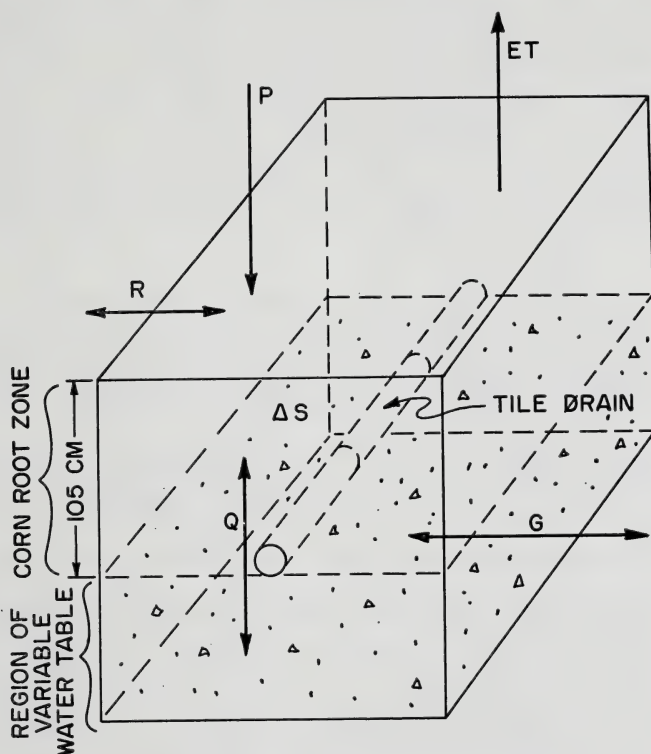


FIGURE 2. Available soil moisture in top 105 cm and depth of water table under corn for: a. 1971 growing season; b. 1972 growing season; and c. 1973 growing season.

western corn belt, since precipitation probabilities are very nearly the same over the entire corn belt in the spring and summer (8), when evapotranspiration demands usually exceed precipitation supply.

The problem is to estimate the amount of soil moisture in the corn root zone which has moved upward from the water table for use by plants. The complexity of this problem can be appreciated from the components of the soil water balance sketched in Figure 3. Precipitation (P) can be measured with standard rain gages. The experimental plots are sufficiently level that runoff or runon (R) was observed to be zero. The evapotranspiration (ET) can be estimated for any period as the difference (ΔS) between soil moisture neutron probe measure-



$$\Delta S = P \pm R \pm G \pm Q - ET$$

ΔS = Change in available soil water

P = Precipitation

R = Surface runoff

G = Horizontal ground water flow

Q = Deep percolation

ET = Evapotranspiration

FIGURE 3. Schematic soil water balance.

ments at the beginning and end of the period, plus any precipitation, *if there is no other inflow or outflow from the corn root zone*. Although this has been assumed for a first approximation, this assumption is not true.

Even when periods with the water table above the tile lines are not considered, there may be downward percolation, or deep drainage from the corn root zone (Q_{∇}), and also water flow upward ($Q_{\blacktriangle}$) as plant roots remove water and create an upward pressure gradient. The horizontal ground water flow in the unconfined aquifer is designated as G . Under large, level monocultures G can be assumed zero, but in smaller plots this term may be troublesome, especially if adjacent plots do not have the same cropping pattern. For example, in Figure 2a, the 1973 water table curves show rises late in the season when there was insufficient rainfall to explain the rise in water table from surface percolation through the 105-cm profile. Test holes in a fallow field immediately to the north of the experimental plots showed the water table to be about 0.5 m higher while test holes in corn and weed plots to the south showed water table levels similar to those measured in our corn plots. The average of several readings in these test holes late in October are shown in Figure 2c. With this higher hydraulic head to the north, it appears that G was non-zero, at least late in the 1973 season.

The daily rates of water table decrease were determined by dividing the difference between water table depth measurements by the number of days in the interval. When the recorders were operating, hourly rates were summed for the 24 hours ending at 8 AM (to agree with time of climatological observations) for the particular interval. Recorder data showed that water table decreases were generally much greater between 8 AM and 4 PM, but showed no nighttime increases in the 3 years. This latter observation suggests that side inflow (G) is probably small or smaller than any upward flux at night.

To differentiate that part of the water table drop due to internal drainage (leakage) from that caused by flow upwards into the root zone, periods were selected when there was sufficient soil moisture in the top 150 cm to meet evaporation demands, but not excess which would drain freely downward (1). To meet this requirement, *i.e.*, $Q_{\blacktriangle} = 0$, periods were selected when the available root zone soil moisture was between 150 and 200 mm. To assume that $G = 0$ the other requirement was that the depth of the water not be too far below the tile drains, or be representative of the general water table level in the surrounding area. In this case only periods when the water table depth was between 110 and 130 cm were used. In the six seasons there were 24 cases which met the qualifying conditions. The average drop of the water table for these 24 cases was 8 mm day⁻¹ with a standard deviation of 1.3. This "base leakage" rate was assumed constant for all water table depths, and is shown as the dashed line on Figure 4 for the second planting, 1973. The higher rates of water table drop (above this line) represent depleted soil moisture by ET and replenishment ($Q_{\blacktriangle}$) from the water table. Rates below this line are attributed to

some type of water table recharge, either from P or G. It is recognized that the deeper the water table the greater the chance for G to be non-zero.

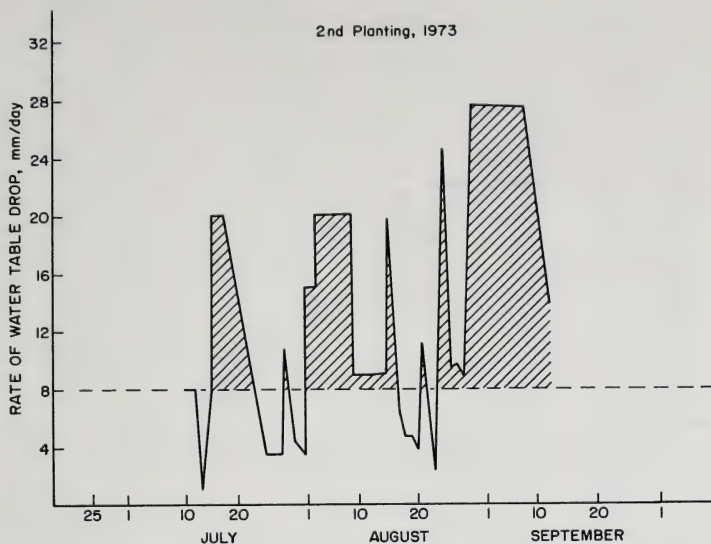


FIGURE 4. Rate of water table drop under second planting corn, 1973 (average of two wells). Dashed line is estimated average deep drainage rate below tile lines into unconfined, aquifer, 8 mm day⁻¹. Rates above this are caused by evapotranspiration, and rates below this by water table recharge with precipitation, percolation or side flow.

To obtain some quantitative estimate of Q in relation to changes in the level of the water table, the available soil moisture in the corn root zone was compared to the depth of the water table. As shown in Figure 5 there is high correlation of the available soil moisture in the 90- to 105-cm layer with the depth of the water table. The same relations hold true for other layers where the root zone or parts of it are sufficiently close to free water that depletions can be replaced quickly by capillary rise ($Q_{\uparrow}$). The average relation between the available soil moisture in the entire 105-cm root zone and depth of water table is shown by the least squares regression line in Figure 6. The greater scatter is caused by including in this relation the more independent surface layers. Points above the line, say, the cluster near the coordinates, 180,180, represent recent rains in the top of the profile. Points below the line, e.g., that near 120,140, reflect periods where corn roots have extracted soil moisture in the surface layers below the indicated equilibrium condition. The slope of -0.73 indicates that for every 1 cm decrease in the water table, available soil moisture is reduced by an average of 0.73 mm. When ET is zero the change in soil moisture caused by a decrease of 1 cm in the water table would average 0.73 mm through the lower boundary of the root zone, i.e., $Q_{\downarrow} = 0.73$ mm cm⁻¹. Conversely, with ET but no deep drainage, we assume that 0.73 mm of available water will move into the root zone, $Q_{\uparrow}$, and cause

the water table to drop 1 cm. In periods where there is a sufficient rate of ET to create a gradient for capillary rise the net Q will be the relative magnitude of the two effects, if we assume no hysteresis.

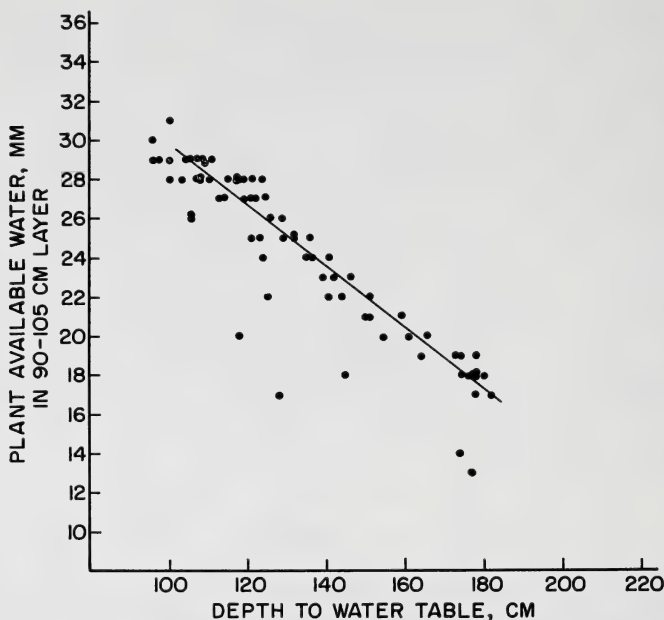


FIGURE 5. Relation between plant available water in 90-105 cm layer and the depth of water table.

Using the relationship in Figure 6, and attributing the additional drop in the water table beyond that of the base leakage rate to the decrease caused by capillary use, we can make a rough estimate of the net volume of water which flows into the root zone from the free water below. For example, in Figure 4, Second Planting 1973, if the hatched area is integrated (34 cm) and is multiplied by the average slope, -0.73 mm cm^{-1} , of the Figure 6 relation, the contribution of Q_{Δ} to total ET is estimated as 25 mm. The total ET for the same period (449 mm) is estimated by correcting evaporation pan measurements (used to estimate potential ET) by crop development and moisture stress factors. The ET contribution from the water table is then estimated as 6% of the total ET for the season. The results for the six planting-seasons are shown in Table 3.

In the last 3 years the amount of moisture used by the corn crop from the water table ranged from as little as 1% in the first planting of 1972 to 11% in the first planting of 1973. Although only three relatively wet years are represented, the contribution from the water table is a significant part of the water used, and it may be more than coincidence that the yields shown in Table 1 are proportional to these Q_{Δ}/ET percentages.

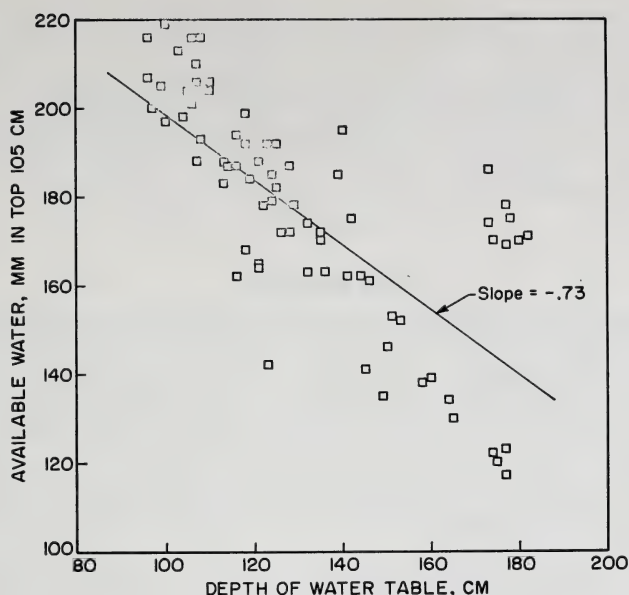


FIGURE 6. Relation between plant available water (mm) in entire corn root zone, top 105 cm, to depth of water table. Least squares regression slope indicates for each 1-cm drop in water table the plant available water in the corn root zone decreases 0.7 mm.

TABLE 3. Percentage of evapotranspiration contributed from water table on tiled Chalmers silt loam, West Lafayette, Indiana.

Crop	Season	Q $\uparrow$ (mm)	Est. ET (mm)	Q/ET (%)
1971 First	5/24-9/15	20	482	4
Second	6/4-9/26	24	443	5
1972 First	5/28-9/19	4	418	1
Second	6/19-10/11	6	415	2
1973 First	5/29-9/20	49	446	11
Second	6/3-9/25	25	449	6

Summary and Conclusions

The observed correlation between the depth of the water table and available soil moisture shows that over most of the growing season the corn root zone is in the capillary fringe of free water. The estimates of the amount of water flux up from the free water level into the corn root zone is comparable to values reported in the literature and can be a significant part of the water requirements of the corn crop, especially in a dry year. Harlan's Brookston seasonal water table patterns, including those for the dry summer in 1967, are very similar to those found on Chalmers (3). Should an extensive drought be experienced this valuable water resource might be conserved and more fully exploited by "drainage management", *e.g.*, stopping tile

line outlet flow from May to September and utilizing the shallow water table for ET rather than stream flow, or even using the tile lines for subsurface irrigation. Galloway and Sisson came to this same conclusion for poorly-drained soils developed on loess-capped till, like Fincastle, and in depressional areas, like Brookston (2). Generally, on these soils in dry years they found corn yields increased with distance from the tile drains.

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ZOOLOGY

Chairman: LES HEARSON, Department of Biology,
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CHARLES E. MAYS, Department of Biology,
DePauw University, Greencastle, Indiana 46135,
was elected Chairman for 1974

ABSTRACTS

An Analysis of the Nerve-mitotic Distribution in the Regenerating Forelimb of the Axolotl, *Ambystoma Mexicanum*. JOHN E. ALBRECHT and LESTER L. HEARSON, Department of Biology, Wabash College, Crawfordsville, Indiana 47933.—An analysis was made of the distribution of nerve fibers, mitotic activity, and cell density. The data are discussed in the light of previous works concerning the roles of nerves, the apical cap, and the wound epithelium in the control of regeneration. A general lack of statistical significance in the results is suggested as a reflection of the interweaving effects had by each. Present findings indicate that in limb regeneration the roles of nerves and the wound epithelium are so interdependent that they preclude the examination of any single influence.

List of Mammals Known to Occur in Belize, Central America. RALPH D. KIRKPATRICK and ANNE M. CARTWRIGHT, Biology Department, Ball State University, Muncie, Indiana 47306.—A list of recent mammals known to occur in Belize was compiled by a search of the literature, by contacting persons who have collected in Belize, and by collecting during the summers of 1972 and 1973. A total of 87 species have been collected in this country. This total includes representatives of 11 orders and 29 families.

Blood Characteristics and Activity of some Neotropical Frogs. DUVAL A. JONES, Department of Biology, Saint Joseph's College, Rensselaer, Indiana 47978.—Erythrocyte count, hematocrit, and hemoglobin concentrations were studied among a variety of frog species in Surinam, and considered in light of the frogs' habits and environment. Active tropical anurans tend to have high red blood cell (RBC) counts and hemoglobin concentrations, and they seem to frequent open habitats. Less active tropical frogs have low RBC counts, low blood hemoglobin concentrations, and seem to be restricted to the interior of well-developed forests. Although size and shape of erythrocytes vary from one species to another, hemoglobin content per RBC changes relatively little. Efficiency of oxygen transport by red blood cells may be a factor which regulates anuran activity and plays a part in habitat preference.

Maternal Behavior in Domestic and Wild Swine: An Ethological Approach. CHARLES SINCLAIR and JACK L. ALBRIGHT, Department of Animal Sciences, Purdue University, West Lafayette, Indiana 47906.—Careful

observations of the behavior of domestic sows (*Sus scrofa domestica*) and their litters were conducted at the Purdue Swine Research Farms and the Purdue Ethology Laboratory. Nursing behavior, teat order of littermates, and diurnal patterns of maternal and piglet activity were examined.

The nursing behavior could be initiated by either the sow or her litter and several stereotyped patterns were found to be effective in initiating nursing. Some of these patterns are also seen in wild swine. The frequency of nursing varies somewhat among litters and becomes less as the pigs grow older. There was no statistically significant difference between day and night with respect to either frequency of nursing or total time spent suckling. This is true for pigs in confinement and those on pasture. Social facilitation is an important factor in determining the timing of nursing.

Teat order is the first evidence of territorial behavior in the pig and is established during the first day of life. We found that both visual and olfactory cues are important in recognition of the "territory." A form of marking occurs. Wild swine establish teat orders. It appears that the more dominant pigs tend to take the pectoral teats. These are richer in milk flow.

Diversity, Stability and Temporal Organization of a Stream Caddisfly Community. VINCENT H. RESH, Department of Biology, Ball State University, Muncie, Indiana 47306.—Light trap collections from the Salt River Basin, Spencer and Anderson counties, Kentucky, from March to November 1971, contained more than 87,000 caddisfly adults, 20,000 of which were identified after sub-sampling. Quantitative collections made with a portable, ultraviolet light trap, beginning 20 minutes after sunset, were either of 1-hour duration or of three consecutive 20-minute periods. Other hourly samples were collected irregularly throughout the night. Forty of the 60 species of caddisflies collected during this study are new distributional records for Kentucky.

Using diversity per individual as a measure of community organization (Brillouin's formula), species diversity estimates of the adult caddisfly fauna have been calculated for 85 quantitative samples. Flight activity, frequency and seasonal range of abundance, and sex ratios of *Athripsodes* spp., *Cheumatopsyche* spp., and *Hydroptila* spp. are discussed. Sex ratios of *Athripsodes ancylus* (Vorhies) adults from light trap collections and mature pupae from benthic stream transect samples, both showed that the ratio of females to males was 112:100.

Blood Clearance and Tissue Uptake of Aminoglutethimide. JAMES F. BELLOT and WILLIAM J. BRETT, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—Chemical and radioactivity labeled (^3H -AG) aminoglutethimide (AG) were injected into the right marginal ear vein of New Zealand white rabbits. Blood samples and tissues were assayed by chemical and radiotracer techniques in order to elucidate the site and mode of action of the drug. Chemical and radiotracer assay methods showed the blood concentration of aminoglutethimide to decrease rapidly for the first 30 minutes and

then level off. Uptake of the drug appeared to be general in that all tissues assayed showed evidence of its presence; however, certain tissues, like the pituitary, showed specific uptake because of high concentrations of aminogluthethimide found in these tissues. Both kidney and liver were shown to function in clearance of aminogluthethimide from the blood.

NOTES

Coccidia from the opossum, *Didelphis virginiana* (Kerr).¹ THOMAS JOSEPH, Department of Biology, Indiana University at South Bend, South Bend, Indiana 46615.—Twenty-eight road-killed and 15 live-trapped opossums from St. Joseph's, Elkhart, La Porte and Marshall Counties, Indiana were examined for coccidia by the zinc sulfate flotation technique. *Eimeria indianensis* was found in three of the road-killed and one of the live-trapped animals (2). The exogenous development of this organism was studied in detail. Two species of isosporans were also observed. One of these, a tissue sporulating species, recovered from two road-killed animals resembled *Isospora boughtoni*. Two attempts to transmit this species experimentally to two caged opossums were unsuccessful. The other isosporan, also recovered from two road-killed animals, was similar to an *Isospora* sp. described from an opossum in Alabama (1). Comparison of photographs of the two species showed that the *Isospora* sp. from Indiana was distinct from the one described in Alabama. Since only a few oocysts of this species were available, experimental transmission was not attempted. As the opossum is an omnivorous animal, it is possible that a few oocysts in its feces could have come from another host eaten by the opossum. Therefore, the two *Isospora* spp. cannot be considered true parasites of the opossum until they are successfully transmitted to captive opossums, or opossums with patent infections with these species are live-trapped and studied.

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Observations on Sea Snakes at Ashmore Reef, Timor Sea.² SHERMAN A. MINTON, Indiana University Medical Center, Indianapolis, Indiana 46202.—Ashmore Reef lies at the edge of the continental shelf between Australia and Timor. It harbors a dense population of sea snakes of several species. Snakes of this and some associated reefs were studied by the R/V *Alpha Helix* expedition in January 1973. Submerged snakes were observed by snorkeling and with scuba gear. Snakes at

¹ Supported by grants from the Indiana Academy of Science, the Society of the Sigma Xi and the Office of Research and Advanced Studies, Indiana University.

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the surface were captured whenever possible. A total of 415 snakes was collected and numerous others observed.

Two endemic species, *Aipysurus foliosquama* and *A. apraefrontalis*, seem to be largely confined to water not more than 10 meters deep. They are small snakes, quite similar in appearance. Although occasionally found together, *A. apraefrontalis* seems to prefer a sandy bottom with sparse coral, while *A. foliosquama* prefers areas heavily grown with coral.

Emydocephalus annulatus, *Aipysurus duboisii*, and *A. fuscus* appear to be basically shallow water species, although all were observed at least once in the 12- to 25-meter zone. All prefer areas of moderate to heavy coral growth but are not confined to them. They tend to congregate along gullies and channels. *Emydocephalus* was the most frequently observed species at most dive sites.

Hydrophis belcheri and *Acalyptophis peronii* were never observed in the shallow water coral habitat but were obtained in good numbers at the surface in water 12 meters or more deep. An individual of *H. belcheri* was observed at a depth of 44 meters apparently foraging on the bottom. This species is almost entirely nocturnal in its surface activity; *Acalyptophis* shows nocturnal tendencies but is also seen during the day.

Aipysurus laevis and *Astrotia stokesi*, the two largest species of the area, were most often noted on the reefs at depths of 5 to 8 meters, but were also seen on numerous occasions around the ship when anchored in water 25 to 45 meters deep. *Aipysurus laevis* shows some degree of curiosity toward divers, but no undoubted instance of aggression was noted. It and *Emydocephalus* were the only species collected at all reefs visited.

Pelamis platurus was recorded on the basis of two juveniles collected and an adult observed. All were in relatively deep water. Observations from other parts of the range indicate this is primarily a deep water, pelagic species. A single *Lapemis hardwickii* was netted from the ship while at anchor. This species is probably accidental and not a part of the regular reef fauna.

All species are specialized feeders. *Emydocephalus* feeds exclusively on fish eggs. *Hydrophis belcheri* feeds entirely on eels, and 80 per cent were one species which lives in burrows. Eels were the only food of *Aipysurus apraefrontalis*, but only a few were examined. *A. foliosquama* feeds on wrasse. *Acalyptophis* feeds mostly on gobies and heliophorids. *Aipysurus laevis*, *A. duboisii*, *A. fuscus*, and *Astrotia stokesi* eat a fairly diverse variety of reef fishes, but there is little overlap in their diets. Snakes tend to eat diurnal fish at night and nocturnal fish by day. The regular presence of venomous toadfish and scorpionfish in the diet of *Astrotia* is noteworthy.

Courtship of *Emydocephalus* was observed on several occasions at 4 to 8 meters depth. A female of this species with almost full-term embryos was also collected. Other species containing advanced embryos were *Aipysurus laevis*, *Hydrophis belcheri*, and *Astrotia stokesi*.

Rabies in Bats of Indiana: 1968-1972

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Abstract

A total of 689 bats from Indiana taken from 1968 through 1972 was examined for rabies, bringing to 1,315 the number examined for this virus since 1965. Of the 1,315, 67 were rabid (5.1 per cent). The greatest number of cases was in red bats, *Lasiurus borealis*, and big brown bats, *Eptesicus fuscus*, but these were submitted in the greatest numbers. The greatest percentage infection occurred in the hoary bat, *Lasiurus cinereus*. Of 51 examined 10 were rabid (19.6 per cent). Bats of the genus *Myotis* were seldom rabid. Rabies was more prevalent in southern than in central or northern Indiana and occurred most often in summer and fall. There were rabies "outbreaks" in Jefferson County in 1967, and in Vanderburgh County in 1967 and 1970, when relatively large numbers of rabid bats were found. However, these cases were widely publicized inducing people to submit large numbers of bats.

Introduction

The first reported case of bat rabies in Indiana was in 1960, in Tippecanoe County. It occurred in the red bat, *Lasiurus borealis*. Information on bat rabies in Indiana was summarized for the years late 1965 through most of 1968 (1) when a total of 626 bats was examined. Of these, 42 (6.7%) were rabid, mostly red and big brown bats (*L. borealis* and *Eptesicus fuscus*), two of the most common bats of Indiana. Cases were also reported in *Myotis lucifugus*, *Pipistrellus subflavus* and *Lasiurus cinereus*. Rabies was more common in southern than in northern Indiana, and was more common in summer and fall than at other times.

The purpose of the present paper is to present information on rabies in bats of Indiana for the period late 1968 through 1972.

Materials and Methods

The methods are the same as in the previous study (1). Bats submitted by citizens of Indiana to the Indiana State Board of Health were examined for negri bodies, then tested by the fluorescent antibody method. Bats were then sent to the senior author for identification and further study.

Again, relatively large numbers of bats came from a few counties, Jefferson, Johnson, Marion, St. Joseph and Vanderburgh. The greatest number was from the latter county because of a publicized "outbreak" in 1970.

A total of 689 bats was examined during this phase of the study, bringing to 1,315 the number of bats from Indiana submitted by citizens and examined for rabies since 1965.

Species of Bats Infected

The greatest number of cases of rabies in bats in Indiana occurred in *Eptesicus fuscus* and *Lasiurus borealis* (Table 1), while the greatest percentages of infection were in *Lasiurus cinereus* and *Pipistrellus subflavus*. Over the country the greatest rates of infection were in *Lasiurus borealis* (1). The incidence of infection in *L. borealis* in Indiana is much greater than that in *E. fuscus*.

TABLE 1. Rabies in bats collected by citizens of Indiana, summarized by species, 1968 through 1972, and totals 1965 through 1972.

Species	1968-1972			1965-1972		
	No. Examined	No. Rabid	% Rabid	No. Examined	No. Rabid	% Rabid
<i>Eptesicus fuscus</i> -----	412	5	1.2	776	29	3.7
<i>Lasiurus borealis</i> -----	186	13	7.0	338	24	7.1
<i>Myotis lucifugus</i> -----	30	0	0	80	1	1.3
<i>Lasiurus cinereus</i> -----	35	6	17.1	51	10	19.6
<i>Pipistrellus subflavus</i> ----	8	1	12.5	24	3	12.5
<i>Myotis sodalis</i> -----	11	0	0	23	0	0
<i>Nycticeius humeralis</i> ----	1	0	0	10	0	0
<i>Lasionycteris noctivagans</i> -	4	0	0	7	0	0
<i>Myotis keenii</i> -----	2	0	0	6	0	0
Totals -----	689	25	3.6	1315	67	5.1

The two species with the highest incidences were both taken in low numbers. Only 24 pipistrelles, *Pipistrellus subflavus*, were examined, but 3 were infected. Ten hoary bats, *Lasiurus cinereus*, of 51 examined were rabid (19.6%). This sample is large enough to tentatively conclude that the hoary bat has the highest incidence of rabies of any Indiana bat, with about 1 of 5 being infected.

Bats of the genus *Myotis* (including most cave bats), are seldom infected (1 of 109, or 0.9%).

Geographic Distribution of Bat Rabies in Indiana

Over the entire study (1965-1972) bat rabies has been found in 23 counties (Table 2), with 6 new county records occurring during 1968-72. They are Clark, Jackson, Madison, Porter, Wabash and White.

A greater incidence of bat rabies was found in the southern than in the northern or central counties, but the reason for this is not known, although it should be pointed out that the three Indiana rabies "outbreaks" were in the southern part of the state. Summarized figures currently are:

TABLE 2. *Rabies in bats collected by citizens of Indiana, summarized by County, 1965-1972. Number in parentheses under No. rabid column indicates number taken in 1968-1972.*

County	No. Examined	No. Rabid	% Rabid
Allen	28	0	0
Bartholomew	7	0	0
Boone	5	0	0
Cass	11	0	0
² Clark	7	1 (1)	14.3
Daviess	11	1	9.2
Dearborn	7	1	14.3
Decatur	6	0	0
¹ Delaware	14	0	0
Elkhart	13	0	0
Fulton	6	0	0
Gibson	7	2 (1)	28.6
Greene	7	2	28.6
Hancock	8	0	0
Hendricks	12	2	16.7
Henry	7	0	0
Howard	10	0	0
² Jackson	15	1 (1)	6.7
Jefferson	192	13	6.8
Jennings	8	1	12.5
Johnson	91	3	3.3
Kosciusko	26	0	0
Lake	26	0	0
LaPorte	4	1	25.0
Lawrence	15	0	0
² Madison	14	1 (1)	7.1
Marion	119	3	2.5
Marshall	8	0	0
Monroe	28	2 (1)	7.1
Montgomery	18	1 (1)	5.6
Morgan	9	0	0
Parke	9	0	0
² Porter	3	1 (1)	33.3
Posey	5	0	0
Putnam	5	0	0
Rush	6	0	0
St. Joseph	82	2	2.4
Spencer	7	0	0
Steuben	6	0	0
Sullivan	5	0	0
¹ Tippecanoe	31	0	0
Vanderburgh	281	26 (16)	9.3
Vigo	23	0	0
² Wabash	6	1 (1)	16.7
Wayne	18	0	0
² White	5	1 (1)	20.0
³ Other counties	84	0	0
Totals	1315	67 (25)	5.1

¹ Counties having rabies reports, prior to, but not during this study.

² New County record for rabies during this study.

³ Other counties in which less than five bats were examined were: Fountain, Grant, Jasper, Knox, LaGrange, (4 each); Clinton, DeKalb, Floyd, Hamilton, Huntington, Miami, Newton, Noble, Randolph, Scott, Warrick (3 each); Brown, Dubois, Fayette, Orange, Perry, Pike, Pulaski, Ripley, Shelby (2 each); Adams, Benton, Clay, Franklin, Harrison, Jay, Martin, Owen, Switzerland, Vermillion, Warren, Washington, Wells (1 each).

North:	6 of 266, 2.2%
Central:	11 of 411, 2.6%
South:	50 of 638, 8.0%

Yearly and Seasonal Rates of Infection

Yearly rates of rabies incidence in the bats examined were:

Year	Per cent Rabid	Number Rabid
1966	8.7	10 of 115
1967	7.3	24 of 328
1968	4.1	9 of 220
1969	2.3	3 of 129
1970	7.0	16 of 229
1971	1.5	2 of 132
1972	1.9	3 of 162

There were 167 bats taken in the spring (March-May) with 5 being rabid (rate of 3.0). During summer (June-August) 835 bats were taken, of which 46 were rabid (rate of 5.5). Comparable figures in fall (September-November) and winter (December-February) were 225, 15, 6.7%, and 88, 1, 1.1%. Thus, summer and fall remain the time of greatest occurrence.

To date, rabid bats have been taken in 8 of the 12 months as follows: January—0, February—0, March—0, April—1, May—4, June—8, July—21, August—15, September—13, October—4, November—1, and December—1.

Jefferson and Vanderburgh Counties

Jefferson and Vanderburgh Counties were the sites of bat rabies "outbreaks" in 1967. Rabies occurred primarily in red bats in Vanderburgh County, and in big brown bats in Jefferson County.

No rabid bats have been found in Jefferson County since 1968 although a total of 53 individuals from there have been examined (including 47 big brown bats and 6 red bats). A total of 155 big brown bats from Jefferson County have been examined (1965-72), of which 12 (7.7%) were rabid. Only 23 red bats have been examined from there, none of which was rabid.

In Vanderburgh County, another "outbreak" occurred in 1970, when 14 of 116 bats submitted were rabid. Seventy-one red bats were included, of which 10 were rabid (14.1%). Also 24 big brown bats were submitted that year, of which only 2 were rabid (8.3%). In 1971 and 1972, 39 red bats were examined from Vanderburgh County, of which only one was rabid (2.6%). Through the entire study, totals of 181 red bats and 43 big brown bats have been examined from Vanderburgh County, of which 18 (9.9%), and 3 (7.0%) were rabid.

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Social Rank and Social Index as Related to Age, Body Weight and Milk Production in Dairy Cows¹

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Abstract

Social Index and Schein-Fohrman rank in 53 dairy cows were highly significantly correlated ($p < 0.001$) with each other. Significant correlations between measures of social behavior and age and weight were also noted. Correlations between social behavior and milk production approached significance ($p < 0.07$). Because of its objective nature and computational ease, Social Index may be substituted for Schein-Fohrman rank. Based upon many scores of dominance and submission and upon lack of statistical significant correlation coefficients, we believe that dominance and submission are not separate ends of a continuum. Therefore, at least four distinct social orders exist in dairy cattle—dominance, submission, leadership-followship, and entrance into a milking parlor.

Introduction

Several authors have studied and verified the existence of a complex social organization within a herd of dairy cattle (1 through 10). They have showed that at least three distinct hierarchial orders (dominance, leadership, and milking) determine priority rights for status, food and water. Milking and leadership were shown to be related (3). The dominance order has been demonstrated to be so stable that a single day's observation substantiates it. The dominance-submission tendencies of calves may be altered by manipulating early feeding and rearing conditions (5). The following factors have been identified as influences on the ultimate dominance pattern: age (seniority), weight, breed, absence of horns, and early experiences.

One interesting aspect of social dominance research has been the variety of schemes used to combine observations into numerical scores. Schein and Fohrman (9) ranked all subjects studied in a straight-line peck order, and did not report any reversals. A least-straight method of analysis has been used (1, 3) to rank animals for various categories of behavior. Donaldson (5) formulated ratios by which various behaviors were then defined for each pair of subjects:

$$\begin{aligned}\text{Aggression} &= \frac{\text{Number of times one animal initiated encounters with another}}{\text{Number of encounters between those 2 animals}} \\ \text{Dominance} &= \frac{\text{Number of times one animal displaced another}}{\text{Number of times animal initiated encounters}} \\ \text{Submission} &= \frac{\text{Number of times one animal yielded to another}}{\text{Number of times animal was approached by the same animal}}\end{aligned}$$

Each subject was scored in relation to every other subject with which it interacted and the scores for each animal were averaged for each day of the experiment.

¹ Journal Paper No. , Purdue University Agricultural Experiment Station.

A majority of previous work in this area has been conducted in herds maintained for research purposes. What effect simultaneous nutritional, physiological and long-term breeding experiments may have had on other behavior studies remains undetermined. This study was devised to determine various measures of social behavior in the Burk-Barton Guernsey dairy herd and to correlate these measures to each other and to physical traits.

Methods

The subjects were 53 Guernsey cows that ranged in age from 25 to 168 months (average 64) and from 680 to 1,500 lbs. in weight (average 1,060). The herd was developed primarily from additions; only 3 of the 53 cows were purchased. Bred heifers usually were introduced into the milking herd between 18 to 26 months old. They were maintained in a free stall-milking parlor installation near Mulberry, Indiana. Feed consisted of an 18% crude protein grain ration fed in the parlor according to milk production. Corn silage was available free-choice at a feed bunk 60 feet long; feeding could occur on either side of the bunk. No hay was fed. A 10-acre field adjacent to the concrete poured feeding lot was available for exercise. A 3-year-old bull was maintained with the milking herd. Although he constantly displaced females and was never aggressively approached by them, interactions with females were not used in any calculations. Milking was usually begun at 6:30 AM and 4:30 PM. The feed bunk was normally filled with silage at the beginning and refilled at the conclusion of each milking. When observations were made of behavior, the first evening was delayed until after all those cows being milked had returned to the feed bunk area.

Observations were made as the cows were feeding between 6:30 PM and 7:30 PM on the four consecutive evenings in autumn and repeated 1 month later in early winter. Each observation and notation of interactions between subjects indicated which subject initiated the encounter and whether the other cow involved yielded (*i.e.*, between Cow 1 and Cow 2, 1+2), retaliated (*i.e.*, 1-2) or neither yielded nor retaliated (*i.e.*, 1-0-2). A portable battery-operated tape recorder was used in the collection of data. This allowed the observer to maintain a continuous watch of the subjects during observation periods.

Measures of behavior were calculated in a manner similar to that described by Donaldson (5).

A measure of behavior called rank was calculated by attempting to arrange the cows in a straight-line peck order as described by Schein and Fohrman (9). This was done by visually inspecting the data and attempting to determine the Alpha, Beta, through Omega, cows. The first and last subjects could easily be placed into definite positions. However, the subjects ranking near the center often were involved in triangular, pyramidal or more complex relationships. An attempt was made to rank near the top of the herd these individuals who consistently were able to defeat those who were near them in rank. The entire process was quite subjective and required frequent judgments besides requiring several hours of tedious labor.

The age of each subject was obtained from herd records and the weight of each subject at the time of her previous calving was obtained from Dairy Herd Improvement Association records. The 305-day lactation, twice daily milking records, standardized to a Mature Equivalent age for milk production, were calculated for each cow based on her most recently completed lactation.

Social index, dominance and submission scores obtained as percentages were converted to arcsins ($\phi = 2 \text{ Arcsin } \sqrt{x}$). Pearson moment-product linear correlation coefficients were calculated by electronic computer between each of the following: social index, dominance, submission, Schein and Fohrman rank, age, weight, and milk production.

Results and Discussion

The total number of encounters recorded was 3,948. Data on individual cows are found in Table 1. Linear correlation coefficients between variables are listed in Table 2.

TABLE 1. *Individual data for the dominant, mid-dominant, submissive and purchased cows.*

Cow	Social Index	Dominance	Submission	Schein-Fohrman Rank	Age (Months)	Weight (lbs.)	Milk Production (lbs./lactation)
21 ³	1.41	2.16	2.41	37	55	1070	6800
26 ¹	2.61	2.55	2.01	1	113	1090	8780
28 ³	1.69	2.25	2.44	33	47	1220	7930
33 ³	1.88	2.70	1.97	8	97	1500	7050
39 ²	1.58	2.24	2.20	28	46	1020	6440
41 ⁴	0.35	0.84	2.31	53	39	680	6040
Mean	1.55	2.36	2.43	27	64	1060	7350
Standard Deviation	.54	.40	.25	15	30	150	1420

¹ Dominant cow; ² Mid-dominant cow; ³ Purchased animals; ⁴ Submissive cow.

Social index and rank (9) were significantly correlated ($r = 0.85$, $p < 0.001$), indicating that these two measures were interpreting essentially the same behavior. There was a significant correlation of Social Index to age ($r = 0.75$, $p < 0.001$) and of rank to age ($r = 0.86$, $p < 0.001$). This is in agreement with previous findings (3, 9). The correlation between Social Index and weight approached significance ($r = 0.32$, $p < 0.07$). The correlation between milk production and Social Index approached significance ($r = 0.25$, $p < 0.07$). Schein and Fohrman rank correlated with milk production showed a slightly higher correlation coefficient ($r = 0.33$, $p < 0.06$). These correlations are similar to those found by Schein and Fohrman (9) ($r = 0.28$) but considerably larger than that found by Dickson (3) ($r = 0.07$). Part of the difference could be due to the measure of behavior used by each worker. Schein and Fohrman (9) worked in one herd whereas Dickson *et al.* (3)

worked in many herds. In the study reported herein, all correlation coefficients which were negative were obtained when submission was one of the variables.

TABLE 2. *Linear correlation coefficients comparing Social Index, dominance, submission, Schein and Fohrman rank, age, weight, and milk production in dairy cows.*

	Social Index	Dominance	Submission	Schein-Fohrman Rank	Age	Weight	Milk Production
Social Index	—	.534**	— .133	.851***	.755***	.322	.254
Dominance		—	.185	.545**	.422**	.181	.214
Submission			—	— .247	— .280	— .309	— .137
Schein-Fohrman Rank				—	.860***	.400*	.329
Age					—	.333*	.283
Weight						—	.196
Milk Production							—

*** = $p < .001$; ** = $p < .01$; * = $p < .05$.

The mean dominance score was 2.36, the mean submission score was 2.43 and the mean Social Index was 1.55. This can be interpreted to mean that in this herd, when a given cow would initiate an attack, the attacker won. Also, when cows were approached (subject to attack) about 88% of the time they would yield, *i.e.*, lose. These cows tended to initiate only those encounters which they stood a good chance of winning and refrained from initiating encounters with cows to whom they stood a good chance of losing. This can be construed as evidence for social stability in the herd. As noted in the methods sections, almost all the cows studied had grown up in the herd. In other words, this was a very stable herd approaching natural conditions as opposed to assembled dairy herds used in some other behavioral studies. (The only cows purchased were numbers 21, 28 and 33. Cows 21 and 28 were 2 years old at the time of purchase, while 33 was 5 years old when she entered the herd. Number 33 was a large cow weighing 1,500 lbs., with a lower Social Index than would be expected for her age and Schein-Fohrman rank. She also had the lowest submission score: 1.97, and a rather high dominance score: 2.70). Apparently the younger cows had "learned their place" and waited for a position within the social hierarchy. As long as cows generally yield when approached, energy and effort will not be expended to determine which cow has priority but "useful" work (*i.e.*, milk production and weight gain) can more readily be done.

The lack of statistically significant correlations of submission to other quantities seem to indicate that in a stable herd of dairy cows submission is a different kind of social behavior, not merely one end of the dominance-submissiveness continuum. Donaldson (5) also theorizes that submission is a valid measure in its own right, not a part of previously described social orders. It is postulated that Social Index interprets the overall hierarchial pattern within the herd but that submission is separate and distinct from some other previously described social orders: dominance, leadership-followership, and milking.

Social Index and Schein and Fohrman rank show nearly the same correlations with the other quantities measured. Social Index scores were obtained by objectively applying a computational formula to the raw data. Schein and Fohrman rank was calculated by subjectively analyzing raw data and judging rank. The objective nature and computational speed of Social Index suggest its use rather than that of Schein and Fohrman rank.

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Food and External Parasites of the Eastern Mole, *Scalopus aquaticus*, from Indiana

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Abstract

Major foods of moles, *Scalopus aquaticus*, from Indiana were earthworms, scarabaeid larvae, miscellaneous vegetation, Formicidae and carabid beetles.

The most abundant parasites and other associates found in the fur were the flea, *Ctenophthalmus pseudagyrtes*, and the mites, *Pygmephorus* sp., two new species and a new genus of labidophorine mites, *Xenoryctes latiporus* and *Scalopacarus obesus*; *Haemogamasus harperi*, *Androlaelaps fahrenheitzi*, and *Haemogamasus liponyssoides*. Several other forms were found in low numbers.

Introduction

There are several previous studies on the food of Eastern Moles (1, 3, 5, 6). The first two studies dealt with captive individuals. The general conclusion one can reach from these papers is that *Scalopus* feeds primarily on earthworms, insects and insect larvae, and little on vegetation.

There are few reports on external parasites of *Scalopus* in Indiana. The flea, *Ctenophthalmus pseudagyrtes*, is common (8, 11, 12). One specimen each of two other fleas, *Stenoponia americana* and *Opisocrostis bruneri*, have also been reported (12). Wilson (12) also reported the tick, *Dermacentor variabilis*; and (11), the mite, *Androlaelaps fahrenheitzi*; and beetle, *Leptinus americanus* (= *testaveus*).

The purpose of this paper is to present information on the food and external parasites of *Scalopus aquaticus* (Linnaeus) in Indiana.

We express our appreciation to Dr. R. B. Loomis (Long Beach State College, Long Beach, Cal.) and Dr. C. S. Herrin (Brigham Young University, Provo, Utah) who confirmed identifications of *Euschoenogastia* and *Hirstionyssus*, respectively.

Methods

A total of 113 Eastern moles was examined, 70 from Vigo County, the remainder from Gibson, Lawrence, Marion, Marshall, Newton, Owen, Parke, Pulaski, Putnam, St. Joseph, Sullivan, Tippecanoe, Vermillion and White Counties. Most were taken in Nash mole traps. Stomach contents were placed in petri dishes of water, and the material teased apart and gently washed with one or two changes of water. Identifications were made by comparison with reference material. Visual estimates were made of the volume of each food in each stomach. These values for each food were later summed, and divided by the total number of stomachs containing food x 100, giving the per cent volume for each food (Table 1).

TABLE 1. Food of 90 moles, *Scalopus aquaticus*, from Indiana.

Item	% Volume	% Frequency
Earthworms -----	26.8	87.8
Scarabaeid larvae -----	13.9	32.2
Miscellaneous Plant foods -----	9.0	40.0
Formicidae -----	7.2	48.9
Carabidae -----	5.6	28.9
Ant pupae -----	3.3	17.8
Unidentified insect -----	3.1	16.7
Chilopoda -----	3.1	21.1
Coleopterous larvae -----	3.0	18.9
Scarabaeidae, adults -----	2.6	7.8
Lepidopterous pupae -----	1.9	8.9
<i>Digitaria</i> seeds -----	1.9	2.2
Lepidopterous larvae -----	1.9	7.8
Oats or wheat seeds -----	1.5	2.2
Unidentified material -----	1.4	6.7
Carabid larvae -----	1.2	6.7
Sorghum seeds -----	1.1	1.1
<i>Endogone</i> -----	1.1	2.2
Spider -----	1.0	5.6
Other foods ¹ -----	---	---

¹ Other foods having less than 1% volume were (in order of decreasing volume) as follows: Unidentified Coleoptera, *Elymus* seeds, cantherid larvae (*Chauliognathus*), Lepidoptera, corn, unidentified insect larvae, elaterid larvae, grass stems, *Cicindela repanda*, *Prunus* seeds, *Physalis* fruit, unidentified fungi, insect eggs (Orthoptera?) unidentified Hymenoptera, flesh, Lygaeidae, grass seeds, slug (*Deroceras*), sowbug, tipulid larvae, unidentified dipterous pupae, unidentified seeds, Curculionidae, *Cerastium* seeds, *Cyclorhapha* pupae, Gryllidae, dipterous larvae, moss, hymenopterous larvae.

Each mole was examined for external parasites by brushing the fur with dissecting needles while using a 10 to 70x zoom dissecting microscope. Parasites were counted, or their numbers estimated when they were abundant. They were placed in Nesbitt's solution containing acid fucsin to relax, clear and stain them, and then mounted in Hoyer's solution.

Results

Food Habits

Food was present in 90 stomachs (Table 1). The single most important food was earthworms, at 26.8% of the volume. Other important foods were scarabaeid larvae, vegetation, ants (Formicidae), and ground beetles (Carabidae). Animal material totaled 80.8% of the volume of food, and included 23.3% various kinds of larvae, 10.5% ant pupae and adults (and some larvae) and 9.6% various kinds of adult beetles. Plant foods comprised 18.2% volume, including 7.3% seeds. Miscellaneous plant foods consisted of parts of root, stems and leaves, much of which may have been taken incidentally or may have been in the intestinal tract of earthworms or other animals. Some foods eaten at relatively high rates by other Indiana insectivores (9), but at relatively low rates by *Scalopus* were lepidopterous larvae, slugs and snails, crickets, and spiders, probably because these items tend to

remain mostly above ground. The fungus, *Endogone*, often found in small mammal stomachs (7), including shrews (9), was found in only two moles although it made up 80% of the volume in one. Other items found in trace amounts but not included in the table are adult Staphylinidae, Cynipoidea, stratiomyid larvae, and *Chenopodium* seeds.

External Parasites and other Associates

A total of 104 moles was examined for external parasites, of which 80 (76.9%) were infested with at least one individual. Three species of flea, one beetle, one biting louse and at least 13 mites were found, in addition to 78 miscellaneous mites, apparently free-living forms (not included in Table 2).

TABLE 2. *External parasites and some other associates of 104 Eastern Moles, Scalopus aquaticus, from Indiana.*

Parasites	Total Number	Avg. No. per Mole	No. Moles Infested	% Infested
Siphonaptera (fleas) ¹				
<i>Ctenophthalmus pseudagyrtis</i> Baker -----	139	1.34	46	44.2
Coleoptera (beetles)				
<i>Leptinus americanus</i> -----	9	0.09	4	3.8
Anoplura (sucking lice)				
<i>Haematoponoides squamosus</i> (Osborn) -----	32	0.31	4	3.8
Acarina (mites) ¹				
<i>Pygmephorus</i> sp. -----	925±	8.89	42	40.4
<i>Scalopacarus obesus</i> Fain & Whitaker -----	823±	7.91	12	11.5
<i>Haemogamasus harperi</i> Keegan -----	282	2.71	13	12.5
<i>Androlaelaps fahrenheitsi</i> (Berlese) -----	146	1.40	21	20.2
<i>Haemogamasus liponyssoides</i> Ewing -----	97	0.97	30	28.8
<i>Eulaelaps stabularis</i> (Koch) -----	13	0.13	6	5.8
<i>Xenoryctes latiporus</i> Fain & Whitaker -----	7	0.07	2	1.9

¹ Less than five individuals of each of the following forms (number in parenthesis), were also taken. Siphonaptera: *Nearctopsylla genalis* Baker (2), *Stenoponia americana* (Baker) (1), *Cediopsylla simplex* (Baker) (1); Acarina: *Euschoengastia trigenuala* Farrell (3), *Ornithonyssus bacoti* (Hirst) (2), *Haemogamasus ambulans* (Thorell) (1), *Hirstionyssus blarinae* Herrin (1), and *Macrocheles* sp. (1).

The only common flea of the mole in Indiana is *Ctenophthalmus pseudagyrtis*, of which 134 individuals were seen. Two specimens of *Nearctopsylla genalis* were taken on one mole from St. Joseph County, constituting the first record of this flea from Indiana. There are relatively few records of this species, but it is referred to as a flea of shrews and moles (4). *Stenoponia americana* has been reported from shrews and other species from Indiana (9, 10, 12). *Cediopsylla simplex* is a flea primarily of cottontail rabbits (*Sylvilagus*). The one specimen found on the mole can be considered accidental.

A few beetles, *Leptinus americanus*, were found on *Scalopus* and were previously reported from Indiana (9, 11).

Sucking lice, *Haematoponoides squamosus*, were found on only two moles. This species had not previously been reported from Indiana.

The most abundant mite on the moles was listed as *Pygmephorus* sp., but two species of this genus are included, and are currently being described as new by Dr. S. Mahunka of the Hungarian Natural History Museum in Budapest, Hungary. These tiny mites were sometimes in large numbers and have also been found on *Blarina* from Indiana (9). The relationship between these mites and the moles is not understood. One specimen of *Macrocheles* was also taken.

Two labidophorids, both new species were taken and have recently been described (2), one being placed in a new genus *Scalopacarus*. The species are *Scalopacarus obesus* and *Xenoryctes latiporus*. Both consist of hypopi or transport forms; the adults of neither have been found.

The remainder of the mites are normally thought of as parasitic forms. *Haemogamasus harperi*, *H. liponyssoides* and *Androlaelaps fahrenheitsi* are the forms that could be referred to as the regular parasitic mites of *Scalopus aquaticus* in Indiana, with *Eulaelaps stabularis* being infrequent. Species of mites reported here for the first time from Indiana are *Haemogamasus harperi* and *Hirstionyssus blarinae*. The following species have not been previously reported from *Scalopus*: *Euschoengastia trigenuala*, *Ornithonyssus bacoti* and *Hirstionyssus blarinae*.

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A Summer Concentration of the Indiana Bat, *Myotis sodalis*, in Wayne County, Indiana

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Abstract

On 3 August 1971, a group of about 50 bats flew from a dead elm tree (*Ulmus americana*) as it was bulldozed over. Eight were captured and identified as Indiana bats, *Myotis sodalis* (two adult females, four immature females, and two immature males, now in the collection of the Joseph Moore Museum). This represents the first record of a maternity colony of this species. During intensive mist-netting along a stream 500 meters south of the elm in the summer of 1972 and 1973, 193 bats were captured. A high percentage of these (16.3%) were *Myotis sodalis*. This led us to believe the colony had returned to the immediate vicinity of the elm tree. However, we were unsuccessful in locating a specific colony site.

Introduction

In past summers the Indiana bat, *Myotis sodalis*, has been collected by shooting (5), it has been found under bridges (6), individuals have been found with little brown bats, *Myotis lucifugus*, in maternity colonies (Cope, unpub. data) and mist-netted in Missouri (3) and Ohio (Koestner, unpub. data). Summer-male colonies of this species are known to occur in caves where winter populations of *Myotis sodalis* have been found (4). Little, however, is known concerning the summer activity of this species (1). Winter populations of the Indiana bat declined rapidly in the past decade (2; and Cope, unpub. data). The Bureau of Sport Fisheries and Wildlife (1966) and International Union for Conservation of Nature and Natural Resources (1968) have placed the Indiana bat on the rare and endangered species list.

On 3 August 1971, Mark Wright bulldozed a dead elm (*Ulmus americana*) tree in a hedgerow near the Nolands Fork River, north of Webster, Wayne County, Indiana. He captured 8 of an estimated 50 bats which flew out from under the loose bark of this tree as it was pushed over. These bats, two adult females, two immature males and four immature females, were taken to the Joseph Moore Museum on the Earlham College campus where they were identified as *Myotis sodalis* and entered in the Museum collection, M3278, M3279, M3280, M3304, M3305, M3380, M3381, and M3382. These bats represent the first reported maternity colony of *Myotis sodalis*.

Materials and Methods

Personnel of the Joseph Moore Museum mist-netted over Nolands Fork River about 500 m south of the site where the maternity colony was destroyed, from 6 July 1972 through 5 October 1972 and from 13 June 1973 to 6 October 1973. This totaled 58 net nights in 1972 and 112 net nights in 1973. All bats were captured in 9 or 12-m mist-nets placed at right angles to the river, between pipe or conduit supports.

One 9 m high netting station was established by placing four 9-m mist-nets on top of each other enclosing the area just below the canopy of a large Sycamore (*Platanus occidentalis*) which had branches drooping over the river. The 12-m nets were moveable and placed at different netting sites along the river and adjacent hedgerows. Captured bats were banded with Fish and Wildlife Service bands, weighed, sexed, aged, checked for reproductive condition and released within 15 min of capture time in the summer of 1973, but held until the end of netting time before release in the 1972 operation.

Observations were made on crepuscular and nocturnal activity of bats in the vicinity of the netting sites. This was aided by as many as seven persons spread out along the river bank within radio or voice contact with each other. An ultrasonic sound detector (bat detector) was used to monitor bat activity after it became too dark for visual observation.

Results

A total of 193 bats were captured and banded during the summer of 1972 and 1973: 106 (56%) were big brown bats, *Eptesicus fuscus*; 31 (16%) were Indiana bats, *Myotis sodalis*; 28 (15%) were red bats, *Lasiurus borealis*; 15 (8%) were little brown bats, *Myotis lucifugus*; 8 (3%) were hoary bats, *Lasiurus cinerius*; 3 (1%) were Keen's bats, *Myotis keenii*; and 2 (1%) were silver-haired bats, *Lasionycterus noctivagans*. An extensive search of each building within a 2.5 km radius of the netting site was conducted, and four maternity colonies of *Eptesicus fuscus* with an estimated total population of 140 were recorded. No *Myotis sodalis* were found.

Of the 31 *Myotis sodalis* captured, 25 (81%) were adult females, two (7%) were adult males, three (10%) were immature males, and one (3%) was an immature female. All 25 adult females gave evidence of reproduction. One captured 24 June 1973 was gravid, near full-term, weighing 9.7 g. Fifteen captured between the dates of 15 June and 12 June 1973 were lactating, weighing on the average 7.5 g (9.4 to 6.7 g). The 5 captured after 13 July 1973 had enlarged nipples and worn hair around the nipples indicating recent nursing. At least some of the young were independent of the mother shortly after this time as the first immature was netted on 18 July 1973.

In the summer of 1973, crepuscular flight patterns were routinely studied. *Myotis*, probably *sodalis* because they were five times more abundant (according to banding data) than *Myotis lucifugus*, had established a flight pattern along a hedgerow parallel to the river. These flights were very direct, taking as little as 20 sec to fly 300 m. These bats when monitored with a bat detector produced sounds which indicated direct flight rather than the rapid, irregular, clicking notes associated with feeding behavior. When the bats reached the site where the 9 m high net was located they turned and fed near it, sometimes being caught, but mostly flying around or over the net. From these data it seemed that the flight patterns were originating from somewhere in the hedgerow. Monitoring 40 to 50 m northeast of the starting point

of the hedgerow at dusk with the bat detector, revealed no bat activity. In the summer of 1973 we noted this flight pattern of *Myotis* up to 15 July. (After this date the flight pattern became inconsistent and we were unable to predict where the bats would feed.) Perhaps when the young became independent the flight pattern and habits of the bats changed.

Discussion

Myotis sodalis is uncommon in samples of bats netted over streams in Indiana and Ohio. Cope (unpub. data) netted in six Indiana counties on 24 netting nights but failed to capture a single *Myotis sodalis* in 141 bats captured. Koestner (unpubl. data) netted for 21 nights in nine southwest Ohio counties capturing 201 bats of which only two (1%) were *Myotis sodalis*. Since 16% of our bats were *Myotis sodalis* and because of the special flight patterns observed in the summer of 1973, we have concluded that our nets were within the home range of a *Myotis sodalis* colony.

Myotis sodalis have a strong homing instinct to their hibernacula (4). As high as 80% of banded *Myotis sodalis* return the following year to the same cave where banded (Cope, unpub. data). It seems likely therefore that *Myotis sodalis* displaced from the elm tree in 1971 homed back to the same general locality in subsequent years.

Myotis sodalis apparently developed a consistent flight pattern while the young were unable to fly, but as soon as the young became independent, the flight pattern and feeding habits changed. Efforts to locate the maternity colony of this group of *Myotis sodalis* were unsuccessful.

Efforts to locate *Myotis sodalis* maternity colonies will be aided by a grant supported by the Department of Interior through a contract to the World Wildlife Fund in the summer of 1974.

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INDEX

- ABEL, M. D., 431
- Absorption, seismic energy, 292
- Acid mine drainage, impact of, 239
- AGUIRRE, G., 194
- Ahuili, rite of reversal, nahua, 63
- Air pollution, in Anderson, Indiana, 389
- ALBRECHT, J. E., 465
- ALBRIGHT, J. L., 465, 473
- Alewife, food habits, 179
- Alto Caqueta', cultural marginality, 63
- Altosid SL-10, evaluation, mosquito control, 215
- Amino acid barriers, 125
- Aminogluthethimide, 466
- Amphibian limb regeneration, 465
- ANDERSON, C. A., 64
- Anechoic chamber, 393
- Animal behavior, 473
- Anthropology, physical, 74
- APFELSTADT, G., 63
- Aquatic weeds, biological control of, 173
- Archaeology, Ecuador, 65
- Archaeology, Farrand Site, Vigo County, 63
- Archaic culture, 74
- Argillic, clay accumulation, 433
- Astronomy, computer program for, 385
- Atmospheric, electric conduction current, 431
- Autogeny, northern house mosquito, 215
- BAKKER, G. R., 128
- BALL, D. W., 417
- BANEY, H. F., 124
- Barberry looper, 216
- BARR, R., 95
- BARTOLUCCI, L. A., 136
- BARTON, E. P., 473
- BARTON, G. D., 371
- BASANIVICIUS, C. J., 370
- Bats, infected with rabies, 469
- BAUMGARDNER, M. F., 429
- Beech-maple association, ecological analysis, 136
- Beech-maple forests, successional trends, 133
- Beech-maple groundlayer, community analysis, 134
- Behavior, dairy cows, 473
- Behavior, swine, 465
- Belize, mammal occurrence in, 465
- BELLOT, J. F., 466
- Bellura gortynoides* Walker, 214
- BENDA, R. S., 185
- Benzylpenicillin, reaction mechanism, 123
- BERKEBILE, J. S., 136, 167
- BIGGS, M. E., 242, 284
- BINKLEY, S. F., 162
- BINNION, R. J., 125
- Biological control, potential of white amur, 173
- Biological survey committee, report, 32
- Biology teaching, effect of attendance in, 419
- Biomedical engineering, 195
- Black walnut growth on Indiana soils, 430
- BLAKELY, R. F., 242, 284, 292
- BLAIR, B. O., 139
- BLOOM, W. W., 78
- BOCK, P. L., 122
- BOCTOR, N. Z., 240
- BOENER, C. M., 413, 414
- BONEHAM, R. F., 278
- BORDER, G., 84
- BOSCHMANN, E., 121
- BOWERS, K. L., 382
- BRETT, W. J., 466
- BROOKS, W. D., 250, 421
- BROUILLARD, G. L., 63
- BROWN, L. A., 243
- Bryan nature preserve, ecological inventory, 167
- Bufo lucilia silvarum*, 214
- BURDEN, S. L., 126
- BURGESS, J. W., 214
- BURTCH, R., 412
- Caddisfly, stream, diversity of, 466
- Calcium, accumulation in rat muscle, 113
- Callus, ultrastructure of plastids, 77
- Capsicum*, hybrid of *C. annuum* var. *minimum* and *C. frutescens*, 397
- Carcinoma, prostate, germfree, 341
- Cardinal Creek, Ball State University, analysis of, 135
- CARTWRIGHT, A. M., 465
- CASEROTTI, P. M., 239
- CAUDELL, R. K., 414
- Chalybion californicum*, 220
- Chemical light meter, 155
- CHENCHAYYA, B. T., 193
- CHRISTY, O. B. (memorial), 39
- CHURCH, C. R., 431
- Climatic variation, Indiana, 139
- Chloroplast membrane polypeptides, maize, 95
- Coal mine subsidence, 239
- Coal mine-waste, effects of, 239
- Coal resources, 240
- Coccidia in opossum, 467
- COLGLAZIER, J. M., 424
- College teaching, evaluation of, 417
- Collembola, bionomics, 224
- Collembola, Indiana distribution, 224

- Colletotrichum graminicola*, 351
 COLLINS, H., 243
 COLLINS, J. P., 370
 Community ordination, beech-maple ground-layer, 134
 Computer maps, 399
 Computer program for astronomy, 385
 Computerized flora, 407
 Concept understanding, in science classes, 416
 CONOVER, D. L., 393
 Contributors, instructions for, 485
 COPE, J. B., 482
 Corn anthracnose, 351
 Corn, fuel use for drying, 194
 Corn, water balance, 454
 Corn yields, 446
Coryphista meadii, 216
 Cottontail, use of artificial shelter, 146
 Coupee, type location, 433
 CRAIG, G. M., 369
 CRANE, F. L., 95, 105
 Creationism, 20th Century, 330
 Creationists vs. evolutionists, 412
 Creativity, elementary school science teaching, 411
Crematogaster l. lineolata, 220
 CROVELLO, T. J., 399, 407
Ctenopharyngodon idella Val., 173
Culex pipiens and *C. fatigans*, taxonomic status, 214
Culex pipiens pipiens, autogeny, eastern Indiana, 215
 Cytochrome c_1 , in membranes, 105

 DAILY, F. K. (necrology by), 39
 DALE, R. F., 454
 DAVIS, W. W., 241, 369
 DDT, effect on muscle calcium, 113
 Decarboxylation reaction, kinetics of, 128
 DELLEUR, J. W., 196
 Depth-of-focus, from isoseismals, 292
 DEVITO, A., 411
 Diffusion of ions, 125
 Diquat, effect on *Liriodendron*, 136
 Divergence value, 399
 DONALDSON, S. L., 473
 DONSELMAN, H. M., 136
 DOSKOCIL, M. J., 173

 Earth Resources Technology Satellite, multispectral data, 429
 Earthquakes, in Indiana, 193, 242, 292
 Eastern moles, ectoparasites and food, 478
 EBERLY, W. R., 335
Echinochloa muricata, 78
 Eclipse, solar, 371, 382, 431
 Economic resources inventory, 269
 Ecuador, archaeology of, 65
 EDDY, P., 135
 EDINGTON, W. E., 317
 EDWARDS, P. D. (memorial), 41
 Eggs, mosquito, 213

 ELDER, J. H., 113
 Electron microscopy, CHO cell surface, 84
 Elementary school science, a survey, 413
 Elementary teacher instruction, 414
 ELLIS, L. F., 84
 ELLIS, L. J., 83
 Energy, use for corn drying, 194
 Energy resources, 240
 Environmental education, 407, 415
 Environmental education, interdisciplinary, 414
 Environmental geology, Boone and Tippecanoe Counties, Indiana, 269
 Environmental geology, Howard County, Indiana, 278
 Environmental instruction, 414
 ERRINGTON, P. R., 370
 EULER, D. E., 126
Euphorbia, starch grains in latex, 83
 Evaluation, student, 417
 Evapotranspiration, contribution from water table, 454

 Farrand Site, prehistory of Vigo County, 63
 FAVINGER, J. J., 317
 FELLING, C. E., 77
 Fertilization, effect on oats, 430
 FISCHER, B. C., 155, 162
 Fish, growth and distribution, 185
 Flora of Indiana, revised, 407
 Floristics, 399
 FOLTZ, P. R. (memorial), 42
 Food habits, alewife, 179
 Food habits, of eastern moles, 478
 Forest canopy, light attenuation, 162
 Fossils, Silurian reef and interreef, 301
 Fracture analysis, 243
 FRANZMEIER, D. P., 433, 439
 Frogs, comparative hematology, 465

 Gasometric apparatus, automatic, 128
 Gas turbine engine incinerator, 369
 GAVIN, J. J., 357
 GEHRING, C. L., 77
 Genetics versus evolution, 330
 Geomorphology, Indiana watersheds, 196
 GOFF, C. W., 84
 GOGNOT, T., 241
 GOMMEL, R. A., 431
 GOMMEL, W. R., 431
 Gran plots, 126
 Ground water contaminant decay, 194
 GROVES, W. E., 123
 GUCKER, F. T. (memorial), 43
Gymnocladus dioica, site characteristics, 135

 HARLAN, P. W., 439
 HARMON, H. J., 105
 HART, J. W., 224
 HARTMAN, J. M., 64
 HEARSON, L. L., 465

- HEISER, C. B., JR., 397
 HENDRICKS, D. R., 430
 HERTEL, J. M., 139
 Hexapeptides, cyclic, 122
 HILL, L. S., 121
 Historic structures, restoration, renovation, 241
 HOFFER, R. M., 136
 HOGUE, D. R., 123
 HOLLETT, B., 134
 Holography, 370
 HOPP, W. B., 59
 Howard County, Indiana, 278
 HOWE, R. H. L., 124, 136
 HUFFMAN, G., 420
 HULTS, M. E., 371
 HURLBUT, F. (memorial), 45
 Hydrology, Indiana watersheds, 196
 Hydrology, Kankakee River basin, 193
 Hymenoptera, prey-taking among, 220
- INFANTE, A. J., 121
 Indian Knoll, skeletal population, 74
 Indiana bat, 482
 Indiana plants and animals, described by Linnaeus, 319
 Individualized learning, carrel packets, 414
 Innovation, in science teaching, 411
 Inquiry, in teaching physical science, 414
 Insects, economic, in 1973, 230
 Insects, new state and county records, 230
 Instructions for contributors, 485
 Intellectual development, in science classes, 416
- JACKSON, M. T., 133
 JAUS, H. H., 420
 JOHNSON, H. S., 167
 JONES, D. A., 465
 JOSEPH, T., 467
 JOYNER, J., 214
Juglans nigra, growth on Indiana soils, 430
 Junior Academy of Science, 29
- KAITCHUCK, R. H., 382
 KALBOG, S. M., 122
 Kankakee River Basin, 193
 KELLER, C., 399
 KERN, F. D. (memorial), 46
 KIRKPATRICK, C. M., 146
 KIRKPATRICK, R. D., 465
 KOILE, R. C., 124
 KOLTENBAH, D. E., 125, 369
 KOVACS, W. D., 193
 KRISTOF, S. J., 429
 KROCKOVER, G. H., 412
 KRUGER, T. L., 123, 124
 KULLERUD, G., 240
- Land-use planning, 269
 LaPorte Anomaly, Indiana, 204
 Laticifers, starch grains, 83
- LAWSON, A. E., 416
 LEE, T. M., 196, 215
 LEMBI, C. A., 173
 LEPERA, J. L., 369
 Lepidoptera, aquatic, 214
 Leukemia, therapy of AKR, 341
 LEVENSON, J. B., 134
 LEVINE, E., 214
 Light extinction curve in a forest canopy, 162
 Light measurement, by chemical meter, 155
 Light meter, chemical, use in forest canopy, 162
 LINDELL, J. E., 194
 Linnaeus, plant and animal names of, 319
 Liposomes, cell adsorption, 84
 LOEWENSTEIN, J. W., 128
 LOVE, D. L., 385
- McBEE, E. T. (memorial), 47
 McCLAIN, M. L., 135
 McCOMISH, T. S., 179
 MCGIVERN, J. J., 213
 McHUGH, C. P., 397
- MAGEE, W. E., 84
 MAHLBERG, P. G., 83
 MALCOLM, M. D., 420
 Maize, chloroplast membrane polypeptides, 95
 Maize, tassel seed-2, development, 77
 Mammals, occurrence in Belize, 465
 Manchester College, first biology teacher, 335
Mansonia perturbans (Walker), 216
 Mapping, seismic, bedrock depths and lithologies, 284
 Mapping, seismic, Jasper and Pulaski Counties, 284
 MARLAND, G., 239
Marsilea, spore viability, 78
 Masonry materials, historic, brick, stone, mortar, tile, 241
 Mathematics, women in, 317
 MATHER, I. A., 343
 MEISER, J. H., 125, 369
 Membership (new) list, 52
 Membranes, protein location, 105
 Mercury ore, 240
 MERRITT, C., 155, 162
 MERTENS, T. R., 79
 MEYER, R. W., 218, 230
 Microclimate, in cottontail shelters, 146
 Micromorphological analysis of Indiana soils, 439
 Microwave, exposure facility, 393
 Microwave, generation system, 393
 MILLER, C. W., 389
 MILLER, W. A., 469
 MILLS, R. S., 482
 MINTON, S. A., 467
 MITCHELL, D. A., 371, 382

- Mitochondria, membrane structure, 105
 MODENA, J., 424
 Molecular biology and therapeutics, 357
 Moles, ectoparasites and food, 478
 Mollisols, high organic matter, 433
 MONTGOMERY, B. E., 319
 MOODY, J. C., 420
 MORRÉ, D. J., 78, 86, 113
 MORRIS, C. S. (memorial), 48
 Mosquito control, waste lagoons, Indiana, 215
 Mosquitoes, Delaware County, Indiana, 213
 Mosquitoes, distribution in Indiana, 218
 Mosquitoes, radiation cytogenetics of, 213
 Multiple tills at Wabash, Indiana, 242
 Multispectral satellite data, computer analysis of, 259
 Multispectral satellite data, mapping soil patterns, 429
 MUNSEE, J. R., 32
 MYERS, T. P., 65
Myotis sodalis, summer concentration of, 482
- N-(2-Deuteroethyl)-N-ethyl aniline oxide, 123
 N, N-disthylaniline oxides, 124
 NAD glycohydrolase, pyridine nucleotide cycle, 343
 Nahua, Indian, of Veracruz, Mexico, 63
 National Plant Board, 317
 NEIE, V. E., 414, 415
 NELSON, D. W., 431, 432
 NEWBOLD, H. C., 64
 NEWMAN, J. E., 194
 n-Heptanol solutions, 124
 NICHOLSON, R. L., 351
 NISBET, J. J., 424
 Nitrate in water and soil fertility, 431
 Nucleosides, chemistry of, 357
- Oats, protein increase, 430
 Octapeptide, catalytic properties, 122
 OHM, H. W., 430
 Oil, motor, used, evaluation of, 124
 Opossum, coccidia in, 467
 Optics, minicourse on photography, 415
 Organometallic compounds, stereochemistry, 122
 Oxygen demand tests, 136
- PACE, R. E., 63
 Paleontology, Silurian macrofauna, 301
 Parasite releases, Indiana, 1973, 230
 PARKER, G. R., 167
 PARKS, M. E., 415
 PATTON, J. B., 241
 PEART, R. M., 194
 Peats, Indiana, dating of, 369
 Pectic enzymes, 351
 Penicilloyl-poly-L-Cysteine, 127
 Peroxidase, in HeLa cells, 84
 Peroxidases, 86
- Phenology, five plant species, 139
 Photography, physics minicourse, 415
 Photography, solar eclipse, 382
 Physical science, an inquiry-oriented program, 414
 Planar complexes, 121
 Plant geography, 399
 Plastics, ultrastructure, 77
Pinus, numerical taxonomy study of, 397
 Polarography, 126
 POLLARD, M., 341
 Polonovski reaction, 124
 poly 2' fluoro-2'-deoxyuridylic acid, biological activity of, 357
 POORMAN, L. E., 411
 PORTER, S. K., 124
 POWELL, R. L., 239
 Prehistoric Indians, 74
 Presidential address, 59
 PROVOST, P. J., 63
Pseudomonas putida KBI, NAD glycohydrolase and inhibitor, 343
- Rabies, in bats of Indiana, 469
 Radiocarbon dating, 369
 Radiocarbon dating, Indian sites, 125
 Rainfall, effects of urbanization, 193, 204
 RAO, R. A., 204
 RAO, R. G. S., 204
 Reflection, from surfaces, 369
 Regeneration, Axolotl forelimb, 465
 REIDHEAD, V. A., 64, 65
 Remote sensing, strip-mine analysis, 136
 RESH, V. H., 466
 Resistivity, interrelationship with seismic velocity, 242
 Reviewers, acknowledgment of, 487
 Rhenium (I) complexes of, 121
 RHOADES, J. A., 412
Rhodo spathacea, meiosis in, 79
Rhodo spathacea, reciprocal translocations in, 79
 RICHTER, A. R., 482
 RIGGS, R. E., 74
 ROESKE, R. W., 122
 ROMANO, J., 351
 Root, extraction methodology, 134
 ROSS, M. A., 473
 ROSS, S. J., 439
 RUDMAN, A. J., 242, 284
- SAMPSON, L. K., 83, 84
 SANDERS, F. W., 433
Scalopus aquaticus, ectoparasites and food, 478
Sceliphron caementarium, 220
 SCHMELTZ, L. L., 478
 SCHOKNECHT, J. D., 84
 SCHUDER, D. L., 216
 SCHWARTZ, E., 124
 Science instruction, undergraduate, 415
 Science program for sixth graders, 412
 Science teaching, interest centers, 412

- Science teaching, verbalization, 421
 Sciences, elementary school curricula survey, 413
 Scientists, pictorial depiction by children, 413
 Sea snakes, 467
 Seismic, hazard in Indiana, 193
 Seismicity, midwestern U.S., 292
 Senator mine, Nevada, 240
 SETTE, R. J., 269
 SHAVER, R. H., 301
 SHEA, G. J., 242
 SHIMER, S. S., 241
 SHERWOOD, G. A., 126
 SHROYER, D. A., 218
 Shrubs, beech-maple association, 136
 SIEGEL, A., 125
 Silurian, macrofauna, Indiana, 301
 SINCLAIR, C. L., 465
 SIVERLY, R. E., 213, 214, 215, 216
 Skeleton, cranial traits, 74
 SMILEY, C. L., 419
 SMITH, M. D., 411
 SMITH, J. M., 412
 SMITH, O. H. (memorial), 50
 SMITH, R. J., 146
 SNYDER, H. H., 370
 Social rank, social index, 473
 Soil fertility and nitrate in water, 431
 Soil micromorphological analysis, 439
 Soil moisture, relation to water table, 454
 Soil productivity, 446
 Soils, swell and swale, 446
 Solar eclipse, 371, 431
 Solar system, as educational play, 412
 SPANGLER, G. L., 213
 SPOONER, J. A., 193
 SPROAT, J. M., 136
 STANLEY, P. E., 195
 Starch grains, *Euphorbia* latex, 83
 STEINHARDT, G. C., 439
 Stereochemistry, organometallic reactions, 122
 STEVENS, T. J., 244
 STIVERS, R. K., 431, 446
 Stones, lap polished sections, 241
 STORHOFF, B. N., 121
 STORHOFF, D. F., 127
 Stream networks, Indiana watersheds, 196
 Strip-mining, remote sensing mounting, 136
 STUFF, R. G., 454
 Subsidence, coal mine, 239
 SUSALLA, A. A., 77
 SVOBODA, M., 122
 SWARTZ, B. K., JR., 64
 Swine behavior, 465
 Thermal effluents, effects on fish, 185
 THOMAS, G. P., 369
 TINKLE, W. J., 330
 Titration curves, 126
 Titration errors, 126
 Tobacco, allotment arrangements in Indiana, 244
 TODD, W. J., 259
 TOMLINSON, G. E., 382
 Topography, mitochondrial membrane, 105
 Transverse mercator projection, 250
 Trophylum iodide, 125
 TRUITT, R. L., 341
 TWOHIG, F., 86
 UHLHORN, K. W., 413
 Ultisols, low base status, 433
 ULREY, A. B., 335
 Ultrastructure, plastids in leaf callus, 77
 Universal transverse mercator grid, 250
 Urban land use, identification of, 259
 VAN ATTA, R. E., 124, 126
 VARMA, M. M., 292
 Vegetation zones, statistical differences, 64
 Velocities, Indiana bedrock, 284
 Velocities, Indiana unconsolidated material, 284
 VETTER, R. J., 393
 VIGIL, E. L., 86
 Vigo County, prehistoric Farrand site, 63
 VLB, CHO cell surface, 84
 WAGENMAN, G. R., 432
 WAGNER, E. S., 123, 127
 WARD, G. L., 220
 WARN, D. W., 371
 Wastes, liquid, chemical processing, 124
 Water tables, shallow under corn, 454
 WATERS, D. O., 430
 Watersheds, Indiana, geomorphologic characteristics, 196
 WAYNE, W. J., 242
 WEBB, D. A., 179
 WEST, T. R., 269
 WHALEY, J. F., 242, 284
 WHITAKER, J. O., JR., 469, 478
 White amur, as biological control, 173
 WHITESIDES, G. M., 122
 WIER, C. E., 240
 WILKERSON, J. M., 269
 WILLEY, R. G., 173
 WILSON, C. E., 126
 WINTERSTEEN, B., 113
 WORTHINGTON, A. C., 125
 Yields of soils, 446
 YUNGHANS, W. N., 113
 ZIEMER, P. L., 393



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